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STATE OF MINNESOTA
OFFICE OF ADMINISTRATIVE HEARINGS

FOR THE MINNESOTA POLLUTION CONTROL AGENCY

In the Matter of the Proposed Adoption of Minnresota Rules, Parts 7000.4010 - 7005.4050, Relating to an Acid Deposition Standard and Control Plan.

REPORT OF THE ADMINISTRATIVE LAW JUDGE

The above-entitled matter same on for hearing before Administrative Law Judge Allan H. Klein on January 22, 1 986 , in Roseville , Minnesota. Additional hearings were held on January 24, 29-31 , February 3-4, 6-8, 10-14, 18-20, 24-23, March 4-6, 19, 27-28, April 1-4, and May 1, for a total of 35 days. included in these were evening hearings specifically designed for public convenience in Roseville, Duluth, Hibbing and Rochester. An additional seven preliminary public meetings were held in 1985 at five locations around the State to gather public opinion on the general subject of acid deposition.

This Report is part of a rulemaking proceeding held pursuant to Minn. Star, sec. 14.131 through 14.20 to determine whether the Agency has fulfilled all relevant substantive and procedural requirements of law, whether the proposed rules are needed and reasonable, and whether or not the rules, as modified, are substantially different from those originally proposed.

Members of the Agency panel appearing included: J. David Thornton, the Agency's Acid Rain Coordinator and Bradley J. Beckham, Director of Program development & Air Analysis in the Agency's Air Quality Division. Appearing on behalf of the Agency were Special Assistant Attorneys General Alan R. Mitchell and jocelvn Furtwangler Olson, 1935 West County Road B-2, Roseville, Minnesota 55113. Appearing on behalf of the Department of Natural Resources were Special Assistant Attorneys General Gail I. Lewollan and Stephen E. Masten, 500 Lafayette Road, St. Paul, Minnesota 55146. Appearing on behalf of the Sierra Club, the Friends of the Boundary Waters Wi lderness, the National Audubon Society and Izaak Walton League of America (hereinafter "Coalition of

Environmental Organizations" or "CEO") was Marilynne K. Roberts, Assistant Professor of Law, Hamline University School of Law, 1536 Hewitt Avenue, St. Paul, Minnesota 55105. Appearing on behalf of the North American Water Office were George Crocker and Lea Foushee, 1519A East Franklin Avenue, Minneapolis, Minnesota 55404. Appearing on behalf of Minnesota Power was Philip R. Halverson, Senior Attorney, Minnesota Power, 30 West Superior Street, Duluth, Minnesota 55802. Appearing on behalf of Northern States Power Company was Larry D. Espel, of the firm of Popham, Haik, Schnobrich, Kaufman & Doty, Ltd., Attorneys at Law, 4344 IDS Center, Minneapolis, Minnesota 55402.

Public meetings were held in the spring of 1985 to gather public input on the general topic of acid deposition. The specifics of the proposed rule were not published at the time of these meetings. On February 25, 1985, two public hearings were held in Roseville. A total of 52 persons spoke. On February 26, 1985, a public hearing was held at Rochester, at which 17 persons spoke. on March 6, a public hearing was held in Grand Rapids, at which 13 persons spoke. On March 7, a public hearing was held in Park Rapids, at which six persons spoke. Finally, on April 3, two public hearings were held in Duluth, at which a total of nine persons spoke.

In the spring of 1986, public hearings were also held. The specifics of the proposed rule had been published by that time. The Roseville public hearing, on January 27, 1986, resulted in 17 persons who spoke. The Duluth public hearings on February 3, resulted in a total of seven persons who spoke. The Hibbing public hearing, on February 4, resulted in five persons who spoke. The Rochester public hearing, on February 10, resulted in seven persons who spoke.

The bulk of the hearing time was consumed by the presentation of testimony by a total of 75 "expert" witnesses sponsored by the six major participants.

Approximately 965 exhibits were introduced by the major participants, and approximately 800 submitted by members of the public. The majority of the exhibits from the major participants are reports, while virtually all of the public exhibits are letters. In addition to the more than 800 letters, petitions bearing more than 8,000 signatures indicating support for "acid rain standards to protect Minnesota's natural resources now and for future generations" were received.

This Report must be available for review to all affected individuals upon request for at least five working days before the Agency takes any further action on the rule. The Agency may then adopt a final rule or modify or withdraw its proposed rule. If the Agency makes changes in the rule other than those recommended in this report, it must submit the rule with the complete hearing record to the Chief Administrative Law Judge for a review of the changes prior to final adoption. Upon adoption of a final rule, the Agency must submit it to the Revisor of Statutes for a review of the form of the rule. The Agency must also give notice to all persons who requested to be informed when the rule is adopted and filed with the Secretary of State.

Based upon all the testimony, exhibits, and written comments, the Administrative Law Judge makes the following:

FINDINGS OF FACT

Background, Procedural History and Jurisdiction

1. On April 7, 1980, the Legislature adopted legislation on acid deposition, appropriating moneys to the Pollution Control Agency, the Department of Natural Resources and the Department of Health. The thrust of the statute was to declare acid precipitation to be a present and severe danger, to appropriate money and increase personnel complements, and to mandate research, development and education on the subject of acid precipitation. Laws of Minnesota, 1980, Chapter 490. The Pollution Control Agency was named the lead Agency to coordinate this effort.

2. On March 19, 1982, the Legislature again addressed the issue of acid deposition. It repeated its finding that acid deposition posed a present and severe danger to the ecological balance of the state, and declared its intent to mitigate or eliminate the acid deposition problem, both within the state and outside it. The legislation created a timetable for identifying sensitive areas, adopting an acid deposition standard, adopting a control plan to attain and maintain the standard, and setting a deadline for in-state sources to comply with the control plan. Laws of Minnesota, 1982, Chapter 482.

3. In early 1983, the Agency formed a Technical Review Committee, made up of representatives from the forest, tourist, utility and mining industries, as well as environmental advocates and various state agencies. The purpose of this committee was to discuss various scientific issues and attempt to resolve at least some of them prior to the rulemaking hearings ordered by the 1982 legislation. Public Meeting Tr., 2-25-85, p. 14. These meetings were open to the public, and were usually attended by a larger number of people than the list would suggest.

4. On October 15, 1984, the Agency published a Notice of Intent to Solicit Outside Opinion at 9 State Register 767. Included in that Notice was an invitation for interested persons to attend a meeting to be held on November 15, 1984 in Roseville to discuss procedures to be used in the upcoming rulemaking proceeding. On November 2, 1984, the Administrative Law Judge mailed approximately 20 letters to various persons believed to be interested in the procedural aspects of the hearing, specifically inviting them to attend the November 15 meeting.

S. On November 15, 1984, a planning meeting was held. It was attended by approximately 32 persons representing a variety of particular interests. All the entities which ultimately became major participants in the rulemaking croceeding were represented at the planning meeting. One of the decisions reached at that meeting was that the Agency would conduct a series of public meetings to gather general public comment on the subject of acid deposition.

6. On January 21, 1985, the Agency published a Notice of Public Meetings at 9 State Register 1657. The Notice indicated that public meetings would be held in Roseville, Rochester, Duluth, Grand Rapids, and Park Rapids. in addition to this publication, on January 24, the Agency mailed Notice of Public Meetings to its statutory mailing list and an additional list of persons believed to be interested in acid deposition.

7. During February, March and April, 1985, the public meetings were held

in the previously listed cities. A total of 81 persons spoke. The meetings were transcribed, and exhibits were received. The transcript and exhibits became a part of the record of the 1986 hearings as MPCA Procedural Ex- 3.

8. On November 14, 1985, the Administrative Law Judge sent a letter to all persons who had attended the earlier planning meeting and to additional persons believed to be interested in the subject, announcing another planning meeting to be held on December 12, 1985.

9. On November 26, 1985, the Agency Board passed a resolution authorizing a formal rulemaking proceeding on the proposed acid deposition standard and control plan.

10. On November 27, 1985, the Agency filed the following documents with the Chief Administrative Law Judge:

(a) A copy of the proposed rules certified by the Revisor of Statutes;
(b) The Notice of Hearing proposed to be issued;
(c) A statement of the number of persons expected to attend the hearing and estimated length of the Agency's presentation; and
(d) A statement of additional notice.

ii. On December 3, 1985, Thomas J. Kalitowski, the Agency's Director, issued the Notice of Hearing, setting hearings in Roseville, Duluth, Hibbing and Rochester, to begin on January 22, 1986.

12. On December 11, 1985, Northern States Power Company filed a procedural objection to the proposed rules with Director Kalitowski.

13. On December 12, 1985, the previously announced planning meeting was held in Roseville. It was attended by approximately 20 persons, including representatives from all of the interest groups that later became major participants in the hearing. During the course of that meeting, Northern States Power Company made a formal Motion to sever the control plan from the remainder of the rule. A briefing schedule for that Motion was agreed upon.

14. On December 12, 1985, the Agency filed a copy of the Statement of Need and Reasonableness at the Office of Administrative Hearings.

15. On December 13, 1985, the Agency mailed copies of the Notice of Hearing and proposed rules to its statutory mailing list and to an additional list of persons who had indicated an interest in acid deposition.

16. On December 16, 1985, the Agency published the Notice of Hearing and proposed rule at 10 State Register 1354.

17. On December 23, 1985, the Agency filed a Supplement to the Statement of Need and Reasonableness.

18. On January 6, 1986, the Administrative Law Judge issued the First Prehearing Order. This Order dealt with NSP's Motion to Sever, concluding that certain language originally proposed by the Agency for the control plan was not appropriate language for rulemaking, but that alternate language proposed by the Agency was appropriate.

19. On January 10, 1986, the Agency proposed alternative language for substitution in another part of the control plan. On January 16, a Prehearing Conference was conducted by telephone involving the major participants to discuss the proposed alternative language. On January 17, 1986, the Administrative Law Judge issued a Second Prehearing Order, approving the Agency's alternate control plan language as suitable rulemaking language.

20. On January 17, 1986, the Agency filed the following documents with the Administrative Law Judge:

(a) The Notice of Hearing as mailed;
(b) The Agency's certification that its mailing list was accurate and complete;
(c) The Affidavit of Mailing the Notice to all persons on the Agency's list;
(d) The names of Agency personnel who would be representing the Agency at the hearing, together with the names of other witnesses solicited by the Agency to appear on its behalf. This list was contained in the Statement of Need and Reasonableness filed earlier;
(e) A copy of the State Register containing the proposed rules; and
(f) All materials received pursuant to the Notice of Intent to Solicit Outside Opinion which had been published at 9 State Register 767 on October 15, 1984, including, by reference, the transcripts of the 1985 public meetings.

The above-listed documents were available for inspection at the Office of Administrative Hearings from the date of filing to the date of hearing. In addition, all of the documents filed earlier were also available. No person requested access to any of the documents at any time prior to the hearing. No prejudice occurred as a result of the Agency's late filing of any documents.

21. The hearings commenced on January 22, 1986 as noticed. Hearings were held on a total of 35 days, with the last one being held on May 1. The period for submission of written comments and statements remained open through May 21, and the period for submission of responses remained open until May 27, at which point the record closed.

22. On February 7, 1986, the Agency mailed a letter to all Minnesota utility companies potentially affected by a proposed change in rule language informing them of the change, and informing them of the hearing scnedule. No utility came forward as a result of this mailing. Proc. Ex. 16.

Public testimonv and Exhibits

23. The testimony and exhibits received from the "public" overwhelmingly favored adoption of the rule -- or a stricter one. Most persons acknowleged that the rule would result in higher electric bills, but they went on to express their support for its adoption nonetheless. The "public" letters did, however, appear for the most part to have been submitted as the result of two or three solicitations from environmental groups. In one case, however, a letter from an industrial concern opposing the rule appears to have been submitted in response to prompting from a utility.

The sheer number of letters does reflect that there are many people in the state who are willing to pay additional amounts to protect resources from acid deposition, although they certainly can not be said to reflect a scientific sample of ratepayers or citizens.

The themes that occurred most frequently were:

description of using a specific resource, and value to the writer;
fear of destruction;

willingness to pay for preservation;
reminder of "trusteeship" concept -- that we are the trustees of the resource for future generations.

Description of the Proposed Rule

24. The proposed rule consists of two major parts, and additional miscellaneous sections. The first major part is the acid deposition standard itself. Part 7005.4030 establishes the standard at 11 kilograms of wet sulfate deposition per hectare per year (11 kg/ha/yr). The second major portion of the rule is the control plan. It is made up of a number of subparts. The first is an emissions cap, applicable to any electric utility whose facilities in Minnesota have a total combined generating capacity greater than 1,000 megawatts. The emissions cap for such utilities is set at 130% of the utility's 1984 sulfur dioxide emissions. The cap takes effect on January 1, 1990. The second major subpart of the control plan is a requirement that the owner of any electric generating facility whose equipment has a rated heat input of greater than 5,000 million BTU per hour must reduce its sulfur dioxide emissions at that facility to a level consistent with RACT (Reasonably Available Control Technology). This limitation also takes effect on January 1, 1990. The rule also contains definitions, provisions relating to utilities acquiring offsets, provisions detailing how the rule operates in the event of sales of facilities, and other administrative matters. In summary, however, the rule can be characterized as containing the 11 kg/ha/yr standard, and the control plan consisting of emission caps and RACT requirements.

STATUTORY AUTHORITY

25. There is no doubt about the authority of the Agency to adopt rules in this area. It is set forth in a number of places, primarily in the 1982 statute discussed above, the Acid Deposition Control Act. Minn. Stat. 116.44, subd. 2 (1984), provides Is follows:

> (a) By January 1, 1986, the Agency shall adopt an acid deposition standard for wet plus dry acid deposition in the acid deposition sensitive areas listed pursuant to subdivision 1.
> (b) By January 1, 1986, the Agency shall adopt an acid deposition control plan to attain and maintain the acid deposition standard adopted under clause (a), addressing sources both inside and outside of the state which emit more than 100 tons of sulfur dioxide per year. The plan shall include an analysis of the estimated compliance cost for facilities emitting sulfur dioxide. Any emission reductions required inside of the state shall be based on

contribution of sources inside of the state to acid deposition in excess of the standards.

26. In addition to that specific directive, Minn. Stat 116.07, subd. 2 (1984), authorizes the Agency to adopt "standards of air quality, . . recognizing that due to variable factors, no single standard of purity of air is applicable to all areas of the state.''

27. In addition, Minn. Stat. 116.07, subd. 4 (1984) provides, with respect to air pollution, that the ". . . agency may adopt, amend and rescind rules and standards having the force of law relating to any purpose within the provisions of Laws 1969, Chapter 1046, for the prevention, abatement, or control of air pollution.''

28. While there were some questions during the hearing regarding the proper interpretation of some of these statutes, there can be no question but that the agency has authority to adopt rules relating to acid deposition.

ACID DEPOSITION STANDARD

Introduction

29. The 11 kg/ha/yr standard was selected to protect the most sensitive lakes in the state. Of all of the units in the Minnesota ecosystem, these lakes are the most sensitive to the impacts of acid deposition. Therefore, by setting a standard to protect those lakes, the standard will automatically protect other units of the ecosystem, such as soils, forests, peat, etc. SONAR, p. 3. Most of the attention at the hearing focused on protecting the most sensitive lakes, but there was some attention also focused on other ecosystem units.

Soils

30. Acid deposition cat acidify soils with low buffering capacities by leaching basic cations from the soil and replacing them with the acidic hydrogen ion. However, no Minnesota soils, even the shallow soils in the Arrowhead region, are sensitive enough to be acidified at current deposition rates .

31. Most soil systems have the capacity to store large amounts of nutrients for plant production. This process of nutrient storage is commonly referred to as Cation Exchange Capacity (CEC). Cation exchange capacity is also referred to as a soil's buffering capacity, which means that as acid, for example, is added to a soil system base nutrient ions are stored in sufficient quantities in the soil system to off-set the addition of acid. Soils sensitive to acidification are generally sandy, shallow, and are in areas of high precipitation. These soil types have a lower capacity to store ions, and the high precipitation rates tend to accelerate the leaching of any available bases .

32. Soils systems presently showing signs of acidification due to atmospheric deposition are generally located in Europe and Eastern North America. The soils in those regions are shallow, highly weathered, naturally low in bases, and occur in areas where a greater volume of more acidic

precipitation than that falling in Minnesota. Studies of acidified soils at two European sites, in the Solling Mountains of central West Germany and in Norway near Oslo, and two studies in New York state, in the Huntington Forest and the central Adirondack Mountains, and three ILWAS watershed sites supports this characterization of sensitive soils. At all four study sites, the sum of bases, pH, and base saturation were much lower than even the poorest soils in Minnesota. (NSP Ex. 12). Also, the rain fall pH is lower and the total precipitation is higher at all the sites than in Minnesota.

33. The bulk of Minnesota soils are not very sensitive to acid deposition. (Tr. Volume 2, p. 20). The most sensitive Minnesota soils are the sandy outwash soils of eastern Minnesota and the shallow bedrock soils of the Arrowhead Region. (SONAR, p. 199). Data from selected soils with these geomorphic characteristics were sampled and analyzed according to sum of bases, pH and base saturation percent. (SONAR, p. 200). In addition to these parameters of sensitivity, an acidification model was developed to assess the sensitivity of soils in Minnesota, using the parameters of dry deposition, background hydrogen levels, mineral weathering rates, and climate. From this model, four sensitive classes of soils were generated (SONAR, p. 255) and the sampled soils were placed in their respective classes.

34. Based on the criteria used in the model, none of the modeled groups of soils were rated in the most sensitive class. Several groups of soils were rated as potentially sensitive, (SONAR, p. 267), and all remaining soil groups sampled were rated as nonsensitive according to the model.

35. Compared to the acidified soils of Europe and New York, Minnesota soils have a uniformly greater sum of bases, pH, and base saturation. Under the soil acidification model, no Minnesota soils fall into a "most sensitive" category, and those classed as "potentially sensitive" were admittedly done so conservatively. (SONAR, p. 267).

36. Although some Minnesota soils exhibit the geomorphic characteristics associated with observed (acidified) soils, the current rainfall amounts and pH levels in Minnesota precipitation are significantly lower. (NSP Ex. 12). Dry deposition levels have also been measured as greater in the affected areas than in Minnesota, thereby contributing to their acidity. Finally, the relatively low loadings in Minnesota and the continual wind blown deposition of calcareous prairie dust supports the conclusion that Minnesota soils resource is not presently at risk of appreciable acidification due to atmospheric deposition of sulfate.

Peat

37. The progression of Minnesota's peat resources from mineral-rich fens to naturally acidic bogs is hastened by acidic deposition. Although the

natural transition is fairly rapid, certain rare Minnesota plant species are found to survive only in these transition bogs. Severe acidic deposition may artificially accelerate the natural progression, resulting in a shortened lifespan for these plants. However, the best estimate of sensitivity suggests that current levels of deposition are not adversely impacting Minnesota peatlands.

38. There are approximately seven million acres of peat land in Minnesota. (Tr. Volume 2, p. 146). The peat lands are comprised primarily of two types: minerotrophic (fens), and ombrotrophic (bogs). Minerotrophic peat lands receive base-rich inputs of water as drainage from surrounding soil areas, which help to maintain the peat land at either circumneutral or slightly acidic pH. Minerotrophic peat lands are further divided into two types: forested wetland swamps (PCA Ex. 83) and fens (meadow-like areas characterized by sedges, reeds and grasses). Fens occur as rich fens and poor

fens. Rich fens are characterized as having pH values above 6.0 and calcium concentrations greater than 10. Poor fens are less easily categorized, but generally referred to all peat lands between the bog and the rich fen. (Tr. Volume 2, p. 148).

39. Ombrotrophic peat lands receive their water solely from precipitation and are dominated by acidophilic sphagnum mosses, or by mosses and dwarf black spruce trees. (SONAR, p. 71). Ombrotrophic peat lands are also referred to as bogs. (Tr. Volume 2, p. 147). Bogs are sometimes referred to as raised "sphagnum bogs" because the sphagnum moss carpet accumulates, in mounds and eventually cuts off the in-flow of base rich water from surrounding mineral Soils.

40. The chronological trend of peat land is from fen to bog. (Tr. Volume 13, p. 14). As peat lands age, and the plant carpet layer becomes thicker, the drainage from surrounding mineral soils is unable to pass in and the natural process of moss accumulation with its accompanying organic acids tends to perpetuate the bog-forming process. The raised bogs overlie reeds, sedge, and shrub fens that once received inputs of bases (chiefly calcium bicarbonate) leached from adjacent soil. (DNR Ex. 11). The surface waters of acid bogs are tea colored and are higher in dissolved organic carbon (DOC) than waters of circumneutral fens. (DNR. Ex. 11).

41. Bogs have a natural capacity to buffer inputs of nitrate and sulfate. Nitrate deposited on the surface percolates downward a short distance, but is rapidly taken up by plants for use in the growth process. (Tr. Volume 13, p. 12; DNR Ex. 11., p. 9). A side effect of plant uptake of nitrate is a corresponding generation of alkalinity. (Tr. Volume 13, p. 62). Sulfate deposited at the bog surface percolates further downward because it is not absorbed as completely by plants as the nitrate ion. Studies indicate that microbial processes beneath the surface results in a chemical reduction of sulfate to sulfide. (Tr. Volume 13, p. 12; DNR Ex. 11, p. 9). Sulfate reduction is a microbially-mediated process and occurs in anaerobic oxygen-free conditions. Studies show that from 60% to 93% of annual sulfate loadings are retained as reduced sulfur in bogs across eastern North America. (CEO Ex. 3).

42. The natural transition from fen to bog is fairly rapid. (Tr. Volume 13, p. 19). Excess acid deposition can acidify the surface peat of a fen, before it percolates down and becomes reduced, making conditions hospitable for further growth of sohagnum moss.

The concern with atmospheric sulfur dioxide loadings from anthropogenic sources is that this natural acidification process will be artificially accelerated (Tr. Volume 13, p. 53), resulting in the take over of nature peat lands by sedge meadows, and ultimately sphagnum bogs. (Tr. Volume 13, p. 11).

43. In Minnesota, it has been observed that rare plant species are present in peat lands undergoing the transitional phase to bog formation. Those plants species are: (1) sedge CAREX EXILIS; (2) RHYNCHOSPORA FUSCA: (3) XYRIS MONTANA; and (4) JUNCUS STYGIUS. Because the species habitat is in the transition phase, acidic deposition resulting in acceleration of the bog forming process would speed up the transition phase and destroy the habitat of these plants. Tr. 13, p. 22.

At present time, it is not fully known what the rate or degree of response is in peat lands under specific loading conditions. (Tr. Volume 13, p. 53). It has been estimated that approximately 40-48 kg/ha/yr of anthropogenic sulfate deposition would be needed to overwhelm a bogs natural buffering capacity. (SONAR, p. 206). Deposition at these very high levels is not predicted to occur in Minnesota. (SONAR, p. 206). Therefore, although sensitive peat lands would be more susceptible to acidification due to high levels of organic acids, it is apparent that Minnesota peat lands would not be affected by the current deposition levels in the state, and would be adequately protected by the proposed 11 kg/ha/yr standard.

Forests

44. Assessment of the effect of acid deposition on a forest ecosystem is difficult because of the variability among multiple factors affecting forest ecosystems and because of a significant time lag before manifestation of stress in forest ecosystems becomes evident. Tr. 2, pp. 70, 109. Forest damage has been observed in Europe and eastern North America, but the damage is occurring at deposition levels greater than those currently being received in Minnesota. There is no known damage in Minnesota, but the lengthy time need for damage to become evident suggests caution.

45. Stresses upon forest ecosystems cannot be automatically attributed to air pollution; rather, other forms of stress also have injurious effects. These other mechanisms of forest stress include biotic stresses (insects, fungi, bacteria, viruses), abiotic (wind, drought, low temperature), natural (geochemical and climatic), as well as man-made (fire, harvesting, air pollution). PCA Ex. 74, p. 5 and NSP Ex. 17.

46. A forest under stress from acid deposition will suffer hidden injury (Tr. 2, p. 108) that will serve to increase its sensitivit to stress from other factors. Tr. 9, p. 122. Hidden injury can predispose a tree to injury from other mechanisms, (Id. and Tr. 9, p. 111) and can take many forms, including photosynthetic inhibition (Tr. 2, p. 107), decreased tolerance to frost (Tr, 2, p. 81), chemical imbalances (Tr. 2, p. 81), fine root damage (PCA Ex. 76), decline of mycorrhiza in spruce populations (PCA Ex. 71, p. 6 and PCA Ex. 74, p. 5), and slowed growth exhibited by smaller tree rings (PCA Ex . 72) .

47. Forests exist in conditions where several interactions take place at once. Acidic deposition affects each one of these systems and they will be addressed separately.

48. Foliar damage can affect deciduous trees, such as beech, as well as conifers. PCA Ex. 76, p. 7 and PCA Ex. 74, p. 12. Development of foliar symptoms is influenced by duration of exposure, frequency of exposure, interval between rain events and intensity of rain fall. SONAR, p. 61.

The general conditions under which foliar effects have been observed in the laboratory were after application of acid mists with a pH of 3.0 or below,
for a duration of two to three months. After this period, forest leaves exhibited lesions, necrosis, cell damage, and cuticle damage. SONAR, p. 60.

49. In forest tree species, direct damage as measured by the formation of lesions seems not to occur above pH 3.5 -- NSP Ex. 15, p. 13 -- but lesions tend to increase as acidity increases. SONAR, p. 61 and NSP Ex. 17, p. 16. These low levels at which damage does occur are much more acidic than those of the mean annual precipitation even in the most heavily impacted areas of the U.S. NSP Ex. 17, p. 16. However, the potential for damage cannot be dismissed, since individual precipitation events and cloud moisture can have pH values at or near the threshold levels. NSP Ex. 17, p 16 and PCA En 76, p. 5.

50. Forest canopies tend to neutralize the majority of acids in precipitation by exchanging hydrogen ions for cations such as calcium, magnesium, and potassium. As the acidic precipitation washes over foliage, leaching of nutrients occurs and the cations are then washed off the leaf surface, thereby enriching the throughfall.

Forests having a well developed canopy and understory will buffer acid precipitation before the acidic components reach the forest floor. SONAR, p. 62.

Natural processes that occur in the maturation of forests cause soils to become very strongly acidic to extremely acidic (pH less than 5.0). NSP Ex. 17, p. 7. As the forest matures, the more easily weathered nutrient cations are leached from the surface horizons. SONAR, p. 63. Tree roots in the subsoil absorb these cations in exchange for H+ ions, further contributing to forest soils' natural acidity. NSP Ex. 17, p. 7.

51. In cool, humid, forested regions, where precipitation is high enough to cause severe leaching, extremely acidic soils, known as podzols, are present. Podzols usually form in sandy parent materials and are characterized by an acidic surface horizon and a bleached (eluvial) subhorizon caused by severe leaching by iron and aluminum compounds. PCA Ex. 70, p. 223. The high leaching removes all the basic cations from the surface horizon resulting in a low buffering capacity and eventually very acidic conditions.

52. Certain forests in Europe and in the U.S. have shown evidence of damage from acid deposition. Perhaps the most striking example is the

phenomenon of novel forest decline (NFD) in Germany. This was mentioned by many of the persons who submitted public exhibits.

The most severe damage from NFD occurred in the forest of southern Germany, and monitoring sites have been established in the Harz Mountains, in the Solling forest, and in the Black Forest. NFD is believed to be caused in part by air pollutants, primarily sulfur dioxide. It can occur in locations well removed from known point sources. NFD symptoms are distinguished from a separate decline situation attributable to smoke damage to tree stands in close proximity to industrial sources. Tr. 1, p. 89.

The forest decline phenomenon has been described as a syndrome linked to several different mechanisms in three stages. NSP Ex. 15, p. 3; NSP Ex. 20, p. 123 and Tr. 1, p. 122. First, several factors, including air pollution, can act together to cause stress that will predispose a tree to stress from other factors. This stress is a type of hidden injury, where the tree is stressed but shows no outward signs. Second, inciting or triggering factors such as late frost, drought, insects or air pollution, which are usually short in duration but cause drastic injury, depending on the extent to which the system has been weakened by the predisposing stress. Tr. 2, p. 122. Third, contributing factors like bark beetles, fungi, and viruses can cause noticeable symptoms and can accelerate the decline without being the lethal agent. Tr. 2 p. 123.

53. The problems of NFD have shown a similar effect in the northeastern U.S., where high elevation forests in New York, Vermont, and New Hampshire, have shown marked declines in productivity. Tr. 2, pp. 82-83. These forests, composed primarily of red spruce, balsam fir, and white birch, grow in thin acid soils and are frequently exposed to cloud moisture at high elevations. Cloud moisture in these areas typically averages around pH 3.5 and high wind speeds enhance interception of acidic substances, effectively increasing the acid deposition levels of these forests by three to four times those received by low-elevation forests. PCA Ex. 76, p. 9. NSP Ex. 20, p. 128. The degree of tree mortality has shown, along with other factors, a significant correlation with elevation (PCA Ex. 76. p. 9), and acid deposition has been cited as a stress factor associated with tree mortality in high elevation forests in New York, Vermont and New Hampshire. Id.

As of 1983, of the European zones monitored for acid deposition levels, the Solling site in West Germany was receiving sulfur loadings of 80 kg/ha/yr. Other European sites, such as the Lake Gardsjon site in southwest Sweden and the Harz Mountains site in central Germany, receive about 30 kg/ha/yr sulfur. These latter amounts correspond roughly to the more heavily impacted areas in the northeastern U.S., particularly the Adirondacks in New York and the New Hampshire forests. PCA Ex. 76, p. 7.

54. The proposed rule for Minnesota of 11 kg/ha/yr is well below the level of loadings in Europe and the eastern U.S. which are currently showing damage. Forest injury similar to that already seen in affected areas is unlikely to occur in Minnesota in current loading conditions.

Wetlands

55. There are several different types of wetlands ranging from seasonally flooded ephemeral wetlands to marshes to shallow lakes with large expanses of

open water and then to lakes themselves. The large bulk of wetlands on a national scale are temporary flooded, ephemeral wetlands. Tr. 14, pp. 115-116.

56. Considering that the major concern in the acid deposition problem has been to shallow precipitation-dominated lakes it makes sense that wetlands (many of which receive their water almost exclusively from rainwater and snow melt) should also be sensitive to acid deposition. However, there is little information or data that substantiates this condition. Tr. 14, p. 127. Most of the focus has been on lakes and not on wetlands. Tr. 14, p. 126. From the studies that have been conducted, primarily in the area of mosquito control, temporary wetlands have PHs in the neighborhood of 5.5 to 5.7. Beyond these limited studies, there is no significant data base on wetland pH levels. There is a proposal by the U.S. Fish and Wildlife Service regional office to make a large scale study of wetlands to evaluate their importance in the acid deposition problem. Id.

57. In Minnesota the wetland types that are most important for waterfowl habitat are the temporary and seasonal wetlands. These are used as stopping points by migratory species and receive a high proportion of annual use by breeding pairs and ducks. One particular species that is largely present in seasonal wetlands is the fairy shrimp species. Fairy shrimp is very important as a diet for certain ducks like the pintail duck. Vol. 14, p. 123. These shrimp are also consumed by birds like the blue-winged teal and the shoveler ducks. While the fairy shrimp is fairly well-adapted to low alkalinity environments, it is known to be sensitive to changes in Ph. Studies show that the fairy shrimp is very sensitive to shifts in Ph at or around 5.5 to 5.7. Vol. 14, p. 123. When breeding pairs of ducks settle into a wetland to lay eggs, the female duck must consume large quantities of crustaceans in order to metabolize enough protein to lay an egg. These fairy shrimp are an excellent protein source for this very purpose. This is discussed in detail in Vol. 14, pp. 123-124. DNR Exhibit 40 illustrates how much the diets of ducks in the springtime are dependent on animals to produce eggs. Mallard ducks rely on these crustaceans for 72% of their diet. Gadwall ducks for 72%, the blue-winged teal for 99% and the pintail duck for 77%. Some other species are listed on Vol. 14, p. 125. Because these crustaceans are so important to waterfowl diet during breeding, shifts in Ph due to acidic deposition may affect the populations of these crustaceans and consequently affect the populations of breeding ducks.

58. Wetlands are important to non-game species as well as game species. Vol. 14, p. 126.- Of particular importance is the fact that pesky insects such as the mosquito and the black fly are acid tolerant species and have been known to exist in acidified environments where other insects and organisms (including species that are predators of the mosquito and fly) have disappeared due to the acidification. Vol. 14, pp. 128-129. In fact, the mosquito control program in Minnesota consists of additions of calcium sulfate to the wetlands as a means of upsetting the breeding habitat of mosquitoes and black flies. A beneficial by-product in this program is the addition of calcium to wetland environments, which offsets the impact of acidification. Vol. 14, p.129.

59. The suggestion that lime could be added to wetlands to mediate acidification is not a practical one. Tr. 14, p. 151. The extremely large number of seasonal wetlands across the state makes liming each wetland physically impossible. The Metropolitan Mosquito Control District has identified 58,000 seasonal wetlands in the seven county metro area alone. The ones of greater concern, such as the waterfowl sites, are more likely to be outside of the metro area. Even more impossible would be the large-scale liming of wetlands in remote areas such as the Boundary Waters Canoe Area Wilderness

60. It is likely that wetlands would prove as sensitive as lakes to acid deposition if we had adequate data on them. But the state of the record here reflects the paucity of data that exists on wetlands and their responses to acidification. Therefore, when looking for the most sensitive units of the ecosystem, attention has uniformly focused on lakes. But the data available suggests that wetlands may well become an equal focus for research and concern in the future.

Aquatic Sensitivity: Lakes

61. Precipitation-dominated seepage lakes are the most sensitive aquatic resource in Minnesota that we know of so far. With no buffering inputs from the watershed, these lakes' ability to buffer acidic inputs from precipitation is limited. Lakes do have internal, alkalinity generating, processes that contribute to their buffering capacities. Unfortunately, neither the empirical models nor the mathematical models applied to lakes by the MPCA specifically measured these in-lake processes and the model predictions may be overly conservative as a result.

The sensitivity of a lake to acidification is dependent upon the hydrology and geochemistry of its watershed. These factors determine the chemical weathering rate of the local soils, glacial deposits, and bedrock and the extent to which base cations are released to flow into the watershed. PCA Ex. 334.

62. Two types of lakes are predominantly observed in Minnesota: stream-fed and precipitation dominated. Each has different characteristics.

63. Stream-fed and groundwater-fed lakes are constantly fed by tributary streams or groundwater flow, replenishing the water with new, mineral-rich inflow. As a result of this infeeding and drainage of water, these lakes have a relatively short water residence time. The water flow into these lakes has extensive contact with soils in the watershed and therefore any precipitation acidity is largely neutralized by bases released from soil weathering processes which are carried to the lake. NSP Ex. 251. Due to the base-rich inflow, these lakes are not considered as sensitive to acid deposition.

64. Precipitation-dominated lakes referred to during the hearing as seepage lakes, tend to be much smaller in area and volume than stream-fed or groundwater-fed lakes. PCA Ex. 335, P. 1091, Table 2. Precipitation-dominated lakes are characterized by the fact that most water inputs come from direct precipitation and lake discharges are primarily into the groundwater system through seepage. These lakes tend to have the lowest alkalinity, id., because there is little or no watershed inputs to neutralize any acid precipitation. NSP Ex. 251. There are a large number of Minnesota

lakes classified as sensitive which have surface areas smaller than 100 acres. Of the 474 "potentially sensitive" lakes studied in the Acid Rain Lakes Data base at the State Planning Information Center, over 120 are less than 25 acres in size. SONAR, p. 173. The majority of sensitive lakes in Minnesota are precipitation-dominated lakes, and it is highly probable that there are a significant number of of very small lakes, less than ten acres, which are highly sensitive as well. Tr. 31, pp. 28-29. Acid lakes found in Wisconsin and Michigan are seepage lakes. PCA Ex. 183. Precipitation-dominated lakes also have longer residence times and are influenced more by acid deposition due to less inflow of weathering products that could neutralize acidity. NSP Ex. 251.

65. Alkalinity is the best indicator of aquatic sensitivity because it is the amount of alkalinity, or acid-neutralizingg capacity, that governs how susceptible to acidification the lake will be. SONAR, p. 2. Alkalinity is a measure of the amount of buffering agents, primarily bicarbonate, that are available in a lake to neutralize acid inputs.

Alkalinity can be measured in several ways. In general, It is defined as the sum of ions capable of accepting hydrogen ions minus the free hydrogen ions. Bicarbonate is the main hydrogen ion acceptor In most fresh water lakes SONAR, p. 40.

The threshold for aquatic sensitivity has been determined to be 200 ueq/1 as bicarbonate. Lakes with alkalinities greater than 200 ueq/1 bicarbonate will withstand acid deposition with no effect in the long term SONAR, p. 66. Lakes with alkalinities less than 200 ueq/1 will be expected to experience a decline in buffering capacity and pH which could stress fish populations and have other undesirable impacts. SONAR, p. 167. These lakes are characterized as "potentially sensitive" lakes by the MPCA. Lakes with alkalinities less than or equal to 100 ueq/1 are characterized as "sensitive lakes", and are expected to experience a greater decline in buffering capacity and exhibit greater stress upon aquatic organisms. SONAR, p. 167. Finally, there are 41 lakes which have been labeled as "critically sensitive." Their total alkalinities are less than 40 ueq/1. These are concentrated in four counties: Itasca, Lake, Pine and St. Louis. Of the 41, 8 had pHs between 6.0 and 7.0, 28 had pHs between 5.0 and 6.0, and 5 were between 4.0 and 5.0. SONAR, p. 181.

66. In Minnesota, most of the watersheds that are susceptible to acidification are located in the northeastern corner. A total of 526 lakes are contained within the sensitive areas, while 5,396 lakes are located within potentially sensitive areas. SONAR, p. 170. Many of these lakes have never been sampled. Toe State Planning Information Center has complied a data base of available lake data from four sources: the U.S. Environmental Protection Agency Laboratory in Duluth, the Minnesota Pollution Control Agency, the National Forest Service, and the Minnesota Department of Natural Resources. There are 1,842 lakes in this data base, 474 of these lakes have alkalinity values less than or equal to 200 ueq/1 and 188 have alkalirity values less than or equal to 199 ueq/1. SONAR, pp. 168-176.

67. The color of a lake may have importance for the potential impacts of acid deposition, although the extent to which it is important cannot be quantified from existing data. SONAR, p. 176. Many northeastern Minnesota lakes drain peatlands and bogs, and are thus characterized by water with high concentrations of dissolved organic matter, often bonded with iron, aluminum and other metals. PCA Ex. 336, p. 426. The organic matter is present as weak organic acids, which explains the fact that many brown-stained waters have natural ly lower pH values then similar clear lakes. SONAR, pp. 176-178.

At pH values below 5.0, organic acid-metal chelates have the ability to neutral ize acid, and their greatest buffering capacity occurs in the range of pH 4.5. At that pH, the organic acids can actually exert substantial acid neutralizing capacity. SONAR, p. 178. However, the vast majority of sensitive lakes in Minnesota have a pH greater than 5.0, indicating that colored lakes in Minnesota must undergo acidification before their inherent buffering capacity becomes a factor. Where lakes with low pH values are observed, it is difficult to distinguish whether the depressed pH is due to organic acids or acid deposition.

Of the 188 lakes classified as sensitive in the lake data base described above, 62% were clear in color. Of the lakes classified as critically sensitive (alkalinity less than or equal to 40 euq/1), most are bog-stained waters. SONAR, p. 181. The pH of these critically sensitive lakes ranges from 4.1 to 6.5, with 80% of the lakes having pH less than or equal to 6.0. SONAR, p. 180.

Due to the lack of understanding regarding organic buffering in acidifying lake systems, colored lakes were largely excluded in empirical modeling of lake acidification.

68. The PCA assessed lake sensitivity according to its acid neutralizing capacity. This measurement was based on the Gran titration method used and relied upon by the Environmental Protection Agency in their data base. PCA Ex. 55, p. 25. NSP Exhibit 235, pages 9 and 10 show graphically how the Gran titrated alkalinity is affected by the presence of organics in a sample. Basically, the Gran alkalinity method underestimates alkalinity in a lake when compared to the method of calculating alkalinity by summing the basic cations and subtracting the anions in a lake sample. On page 10 of NSP Exhibit 235, the difference between these two methods of calculating alkalinity is shown to be linearly related to the amount of dissolved organic carbons in a lake. That is, as dissolved organic carbon increases the difference between the Gran technique and the base cations minus anions technique gets higher as well. The general effect of relying on the Gran technique is that lakes will be shown to have a lower alkalinity than they actually have because of the interference by organics with the method.

69. Not all lakes in Minnesota have been sampled for sensitivity. The characteristics of these unsampled lakes may vary widely, but it is likely that there are a significant number of smaller lakes, less than ten acre in size, that may be extremely sensitive to acid deposition. On the other hand,, these smaller lakes may have significant amounts of sediment and long residence times which could facilitate appreciable sulfate reduction in the sediment thereby having an in-lake buffering capacity capable of mitigating the effects of acid deposition. Until more sampling is done, this must remain only speculative.

In-LaKe Alkalinity Generation

70. The Schnoor trickle-down-model (TDM) relied upon by the Minnesota Pollution Control Agency does not fully account for in-lake processes which

add buffering capacity to a lake, and increase pH values. (SONAR, p. 248).
Two major mechanisms of alkalinity production are not specifically included in the dose-response or lake acidification models: (1) acid neutralizing capacity of lakes sediments and (2) sulfate reduction by bacteria in lakes sediments.

Acid Neutralizing Capacity

71. This process is basically described as cation exchange by lake sediments. As waters become more acidic, the primary mechanism of this sediment buffering capacity is the adsorption of hydrogen on the sediment particle with calcium being released to the overlying water, Tr. 12, p. 13. magnesium is believed to be involved in the ion exchange process as well. (SONAR, p. 248).

Release of cations from lake sediments contributes alkalinity to the overlying waters, but the actual processes and the extent to which alkalinity is increased is not clearly known. Tr. 12, p. 19.

Sulfate Reduction

72. Beneath the sediment water interface, bacteria metabolize organic substrates under anaerobic conditions. Tr. 12, pp. 19, 21. As a byproduct of this bacterial activity, sulfate is reduced to a non-acid, sulfide form, producing alkalinity. (SONAR, p. 248). Sulfate reduction occurs in the absence of oxygen, primarily in the hypolimnion, or anaerobic area of the lake. The hypolimnion can best be described as the layer of cold water some distance below the surface layer of water in the lake. Tr. 12, p. 15. Frequently, algae and other oxygen producing aquatic species do not grow down in the hypolimnion and this layer, therefore, becomes anaerobic. Tr. 12, p. 15.

While many researchers think that sulfate reduction is confined to the hypolimnionic portion of lake, some evidence indicates sulfate reduction occurs in shallow (epilimnetic) water sediments. Microbial activity in the sediments is believed to produce anaerobic conditions close the sediment-water interface, making it conducive to sulfate reduction. (CEO Ex. 14, p. 64). The contribution of sulfate reduction from these epilimnetic areas may be large because shallow water sediments often make up the largest sediment area in a lake. (CEO Ex. 14, p. 64).

73. The phenomenon of sulfate reduction occurs in most lakes. Tr. 12, p. 19. However, sulfate reduction is a pH sensitive reaction Tr. 12, p. 22, and the acidification of sediments may inhibit this process. Evidence indicates that sulfate reduction is definitely inhibited below pH 5.0. Tr. 12, p. 22.

The relationship between sulfate concentration in lake water and the rate of sulfate reduction has been described as a first order process. Tr. 12, p. 24. This means that as the sulfate concentration increases, the rate of sulfate reduction increases proportionately. Tr. 12, p. 26. The relationship between sulfate concentration in the water and the alkalinity generated from sulfate reduction has been described as a flux . Tr. 12, p. 25. This means that sulfate concentration may be high in the water decreasing in concentration at the sediment water interface and decreasing dramatically beneath the interface. Similarly, the concentration of alkalinity of sulfate reduction is greatest in sediments, less at the sediment water interface, and is at its lowest concentration in the water overlying the sediments. Tr. 12, p. 25.

74. In seepage lakes, where the only input is from precipitation, sulfate reduction rates range from 18 to 50 milliequivalents per meter squared (meq/m2). However, in drainage lakes, which receive more drainage in-flow and therefore have a somewhat higher sulfate concentration, sulfate reduction rates generally fall between 20 to 70 meq/m2. Tr. 12, p. 29.

Models

Empirical

75. Numerous empirical models exist for evaluating existing lake date and predicting the degree of lake acidification. In this case, the relationship between precipitation pH and lake pH is used to try and explain future trends based on decreased or increased emissions.

76. Two of the more widely used models were developed in Scandinavia, the first by Almer/Dickson, MPCA Ex. 372, which is based on the assumption that calcium and magnesium content should balance the bicarbonate content in lakes and streams unaffected by acidic deposition. When applied to lakes in western Sweden which received acidic precipitation, there was more calcium and magnesium found to be present than bicarbonate, indicating that strong acid inputs were decreasing the bicarbonate level, or increasing the amount of calcium and magnesium being released from the soils and bedrock in the watershed into the lake. SONAR, p. 209. This model predicts, based upon Scandinavian data, that annual sulfate loadings of less than 15-17 kg/ha would be likely to degrade moderately sensitive lakes, or those having alkalinities between 100 to 200 ueq/1. PCA Ex. 173, p. 11; SONAR, p. 209. For more sensitive lakes, it has been estimated that annual sulfate loadings greater than 9-12 kg/ha would likely be on the border line of potential long-term effects. SONAR, p. 209.

77. A second model, similar to the Almer/Dickson curve, was developed by Henriksen in 1979. PCA Ex. 174. It is based on the relationship between pH and calcium and magnesium concentrations in lake water. This empirical model attempts to estimate the preacidification levels of calcium and magnesium and then calculate the change by comparing existing levels with preacidification levels, using the difference as a measure of the extent of acidification of the lakes modeled. Tr. 16, p. 40.

Henriksen's model suggests that precipitation pH of 4.5, and lake water sulfate concentrations of 60 ueq/1, are the maximum tolerable limits for lake waters with 50 ueq/1 calcium or less. SONAR, p. 210. These lake sulfate concentrations correspond with a precipitation sulfate concentration of about 40 ueq/1, which is equivalent to a wet sulfate deposition of approximately 20 kg/ha/yr, given a precipitation rate of 110 cm per year. Highly sensitive lakes with alkalinities of less than 50 ueq/1 appear to be unaffected at precipitation sulfate concentrations of 21 ueq/1, which corresponds to a wet sulfate deposition rate of 10-12 kg/ha/yr. SONAR, pp. 211-212.

The lake water and precipitation chemistry data used to develop the predictions from both these empirical models are based on Scandinavian studies and cannot be blindly correlated to Minnesota conditions.

78. The Henriksen model was applied to lakes in North America by Wright, PCA Ex. 180. Using 15 sets of data from oligotrophic, softwater, Clearwater lakes not subject to known pollutant inputs (other than atmospheric) from across North America, Wright attempted to check the validity of Henriksen's

empirical model in North America. Lakes in acidified areas of North America, when modeled against lakes in pristine "reference" areas, tend to show that an increase in acid deposition leads to an increase in sulfate concentrations in lake water. This increase in sulfate concentration is then compensated for by either a decrease in bicarbonate or a corresponding increase in cations, or a fraction of both. SONAR, p. 217. Based upon these relationships observed in the lake data evaluated, Wright developed an acidification equation which relates two measures of lake acidification, loss of alkalinity and net increase in sulfate. In order to focus the equations specifically on the decrease in alkalinity, which is a better indicator of acidification, Wright calculated the factor F, as an indicator for the change in sulfate compensated for by a change in calcium and magnesium. PCA Ex. 180, p. 60.

The acidification equation is related to the chemistry of precipitation and in Europe and North America there is a close relationship between the concentrations of acid components in precipitation with observed acidification or increase in excess sulfate in lakes. SONAR, p. 218.

79. Using an empirical model quite similar to the one developed by Henriksen, PCA Ex. 31, and modified by Wright, PCA Ex. 180, Rogalla and Brezonik conducted a dose/response study based on lake data from Michigan, Wisconsin and Minnesota. PCA Ex. 182. The data set was screened such that only lakes with alkalinity less than 500 ueq/1 were chosen to develop load response relationships. To avoid use of lakes where natura' acidity from organic acids may have been significant, and because modeling colored lakes is not yet well enough developed, only lakes with color values less than 50 PCU were chosen. Id., p. 2. Selection of lakes based on these criteria reduce the number of lakes used in the model to 505, from a total of 1,547 in the data base available for this study. Id.

The model parameter designed to account for in-lake consumption (reduction) of sulfate is labeled EF, for enrichment factor, An EF less than 1.0 indicates that there are internal sinks, such as sulfate reduction, that are removing sulfate from the lake. An EF greater than 1.0 indicates that there are watershed sources that contribute sulfate to the ake over and above what is deposited from the atmosphere. Tr. 12, p. 99. Approximately 40% of the lakes studied in this model were found to have sulfate sinks, or EFs less than 1.0, while 60% did not. The variability in the behavior of sulfate from lake-to-lake greatly complicates the ability of empirical models to predict acidification.

Rogalla and Brezonik compute alkalinity from an electroneutrality condition, based on the theory that the sum of cations equals the sum of the anions on an equivalence basis. Tr. 12, p. 101. Rearranging the electroneutrality equation gives an equation for alkalinity as a group of anions equal to the sum of cations minus the non-alkaline anions. Tr. 12, p. 102.

The model attempts to describe the acidification process as a large-scale titration of a bicarbonate lake solution by strong acid from crecipitation. SONAR, p. 222. Changes in alkalinity and sulfate were the primary measures of acidification. These calculated changes in lake acidity were then correlated with amounts of acid loading to give a basis for predictions. Tr. 12, pp. 95-96.

Acidification of lakes, as measured by change in alkalinity and change in sulfate, was plotted against precipitation acidity in a weighted regression statistical analysis. The relationship between the lake acidification measures and hydrogen ion in precipitation were found to be statistically significant. SONAR, p. 222. Solving the regression equation for a zero change in lake acidification results in precipitation pH acidification threshold between pH 4.58 and 4.78. Below this range, lakes hearing minimal buffering capacities (alkalinities below 45 ueq/1) would be expected to acidify. The range described corresponds to a sulfate concentration of 12.1 to 14.8 kg/ha for 70 cm precipitation per year. These values are similar to those sulfate deposition threshold amounts estimated for Scandinavian lakes by Henriksen (PCA Ex. 31) and other North American lakes by Wright (PCA Ex. 180). SONAR, p. 223.

An important consideration is that this model's predictions are conservative in that internal lake neutralization mechanisms are not accounted for. SONAR, p. 223.

There are problems, however, with the Rogalla/Brezonik approach. They arise from the same statistical objections directed to regression analyses based on the NADP data base which are discussed at length in subsequent Findings below, under the heading "Precipitation Chemistry." In addition, the averaging of data over a long period of time (years) ignores the varying chemistry of Individual events. High pH/high S04 events are averaged with low pH/low S04 events, etc. Finally, pooling non-homogeneous data across all NADP sites to provide regional data may not give the most accurate picture, because the differences between Sandstone and Fernberg, for example, are lost in the average.

Mathematical Models

80. Two primary mathematical models were used in this proceeding to attempt to assess the impacts of acidic deposition on lakes. The first model, known as the Schnoor "trickle-down" model, is based on a mass-balanced equation for alkalinity in the watershed and the lake. The second model, the Integrated Lake-Watershed Acidification Study (ILWAS) model calculates the volumetric flow rates and concentrations of cations, anions, aluminum, total organic carbon, and organic acids throughout the lake-watershed system.

Schnoor Model

81. The Schnoor "Trick-Down" Model (TDM) is a compartmentalized transport model for acid precipitation assessments in which pollutants "descend" from the atmosphere to the terrestrial canopy where sorption and biotransformations occur. The eight compartments include: atmospheric, snow cover, soil, unsaturated zone, surface water, water table aquifer, bedrock aquifer, surface water compartment outside the watershed, and groundwater compartment outside the watershed. SONAR, p. 224.

The TDM is founded on an alkalinity mass balance equation that simulates a strong acid and base titration through naturally occurring reactions in the ecosystem. Types of strong acid additions for this model include nitrification by soil microorganisms, sulfide oxidation, base cation uptake by vegetation, and soil cation exchange. Types of strong base additions include denitrification, desulfurization, sulfate adsorption by soil, nitrate uptake by vegetation, and chemical weathering. All of these processes are lumped into one kinetic formulation for each compartment. PCA Ex. 184.

82. A significant omission in the TDM is the lack of an input for in-lake alkalinity generation. At the time the model was applied by the MPCA to arrive at a deposition standard, in-lake alkalinity was reflected by a calibration input, labeled the P factor. This factor is plugged into the lake compartment equation and is adjusted to offset negative alkalinity contributions into the lake. Tr. 9, p. 88. The processes summarized into the P factor are sulfate reduction, nitrate reduction, cation exchange, and

weathering of sediments. One of the weaknesses in the Schroor trickle-down-model is that the model fails to account for the first order relationship between sulfate concentration and lake water and the rate of sulfate reduction. In the trickle-down-model, the "p" factor, which subsumes all in-lake alkalinity generating processes into one model input, is calibrated once and not adjusted even when acid is added or subtracted to the model. Tr. 10, p. 94. The ILWAS model has a specific input for ion exchange in sediments and for sulfate reduction. Tr. 10, p. 259.

83. The TDM was applied to four Minnesota lakes: Crum, Moon, Dunnigan and Meander. Precipitation data was input on a weekly basis, Lsing NADP data.

84. The model is designed to predict long-term acidification. Short-term fluctuations are not accounted for. The TDM alkalinity submodel did not yield a significant statistical correlation with actual measured lake alkalinity for all lakes. Correlations between predicted lake pH values and observed values were also statistically insignificant for all lakes. SONAR, p. 234. These poor correlations may be explained by the fact that use of weekly input data forces the alkalinity submodel to use a mean alkalinity and pH for each lake, rather than using actual daily fluctuations in alkalinity and pH. Simulation of daily fluctuations requires daily input data, which was not available to the agency. Similarly, the episodic effects of snowmelt cannot be predicted by the Schnoor model when weekly input data are used. SONAR, pp. 234-235.

85. For each lake, the present mean annual volume-weighted precipitation pH of 4.97 was input for the first 50-year simulation. This pH value was calculated from the Marcell NADP site near Grand Rapids and the Fernberg site near Ely. Each has a volume weighted average precipitation pH of 4.97, according to NADP data. Each 50-year simulation then inputs a progressively lower mean annual precipitation pH level, with a correspondingly higher negative alkalinity input. SONAR, pp. 236-238.

The TDM results showed alkalinity and pH declining in all four lakes as the annual average precipitation pH was simulated as declining from the current level of 4.97 to 4.1. SONAR, p. 238, Crum Lake appeared to be very sensitive to an increase in precipitation acidity, and lost approximately 50% of its buffering capacity when precipitation pH declined from 4.97 to 4.8, id., p. 239. Based upon the modeling results, Crum lake is predicted to acidify (pH less than 5.0) at an average annual precipitation pH of 4.7.

Dunnigan Lake showed a similar sensitivity, losing approximately 30% of

its buffering capacity when average annual precipitation pH decreased to 4.8.
SONAR, p.241. Dunnigan Lake was projected to acidify at an annual average precipitation pH of 4.7.

Moon and Meander Lakes appeared to be less sensitive to acid deposition than either Crum or Dunnigan. Neither lake showed an appreciable loss of alkalinity until the annual average precipitation pH dropped to 4.7. Meander
Lake is a drainage lake, and receives a large portion of its buffering from watershed inputs. The model predicted that it would acidify at an annual average precipitation pH of 4.1. Results of the Meander model run must be viewed with caution in light of the later admission by the modeller that the model was not properly calibrated (neither was the ILWAS for Meander, in his opinion). Tr. 30, p. 134. Moon Lake was predicted to acidify at a precipitation pH of 4.5. SONAR, pp. 243-246.

86. No mechanisms of in-lake alkalinity production were included in the version of the TDM used by the agency in the SONAR, and thus the model tends to overstate the sensitivity of lakes. However, these omissions can be viewed as a margin of a safety that is protective of aquatic organisms, which have been shown to be eliminated from lakes at pH levels as low as 5.8. Based on all of these facts, the Agency determined that a precipitation pH of 4.7 would maintain the sensitive lakes without acidification.

ILWAS Model

87. The ILWAS model was conceptualized for the same purpose as the TDM, that is, to monitor the chemical changes to lake watersheds and lake in particular when the quality of precipitation is changed. Tr. 10, p. 24.

88. The ILWAS model is more sophisticated than the TDM because the ILWAS model tracks more chemical processes and accounts for more ions in the system. It calculates the daily chemical fluxes associated with water flows and simulates the flow of 18 individual chemical species, The basic design of the model selects a site, divides its spatially into compartments, both horizontally and vertically. Horizontal compartments include land, lake and stream components; each of these is further subdivided into subcatchments, as necessary, to reflect the actual field conditions. The study area is then segmented vertically to account for the forest canopy type, snowpack, and soil layers. Field measurements are then collected and fed into the model simulation.

Precipitation inputs were made daily on the ILWAS model. NSP Ex. 201, pp. 1-3.

89. The ILWAS model was applied to Meander Lake because it has a low alkalinity, shallow soils, forest regrowth, and because it qualified as a sensitive lake according to MPCA criteria. Individual measurements, including soil samples, water samples, wet and dry deposition samples, snow data, and lake sediment samples were collected at Meander Lake for the model run. Tr. 10, pp. 125-126.

The ILWAS modelers predicted the net change in alkalinity and net change in pH of Meander Lake when sulfate deposition was increased by 50%, and 100%, and when it was reduced by 50%. Increasing total sulfate loading by 100% from 14.3 kg/ha/yr to 28.6 kg/ha/yr decreased the average lake water alkalinity by 32 ueql/1 in 20 years. A 50% increase in sulfate loading decreased alkalinity by 17 ueq/1 in 20 years. When the sulfate loading was decreased by 50% (from

14.3 kg/ha/yr to 7.2 kg/ha/yr) the lake water alkalinity increased by 16 ueq/1 by the end of the 20th year. NSP Ex. 208, p. 4-4.

Translating these changes in alkalinity to changes in pH, the 50% increase scenario yielded a predicted pH drop from 6.1 to 5.95. The 100% sulfate increase scenario resulted in a predicted drop from 6.1 to 5.65. When sulfate loading was decreased by 50%, the model predicted an increased pH, from 6.1 to 6.2, over 20 years. Id.

The conclusion from the ILWAS model run on Meander lake is that under current loading conditions, Meander Lake has enough buffering inputs from the surrounding watershed to maintain alkalinity at 70 ueq/1 and maintain its pH at 6.1. Both of these levels are above what is considered critically sensitive by the Agency.

go. The ILWAS model had not been run on a true precipitation-dominated lake at the time of this hearing. Preliminary data on Crum Lake was available, but final results are not in the record. Near the end of the hearing, preliminary results from the ILWAS model's preditions for Crum Lake became available. They suggest that over 20 years, if the sulfate loading were increased by 50%, the impact on Crum Lake would be only a tenth of a unit drop in pH. Tr. 30, p. 15. This is because of the substantial sulfate reduction occurring in Crum Lake. Id. However, the timing of this data left no real opportunities for comment, review or verification.

AQUATIC ORGANISMS

91. The elimination of aquatic organisms is the primary reason for concern over decreasing lake pH as a result of acidic deposition. Progressively lowering pH levels in lake water can have a deleterious effect on the aquatic food web. Of particular concern is the discovery that key organisms in the food web, relied upon by game fish, may be eliminated from the system at higher pH levels than previously believed.

Sensitive lakes contain various populations of fish. Some of the major groups found in sensitive lakes are trout, walleye, the sunfish family (including smallmouth bass, largemouth bass, bluegills, sunfish and crappie), northern pike, and the white sucker. Tr. 14, p. 75. Other important organisms include minnows ant crustaceans.

92. The progressive deteriorating effect that acidification can have on aquatic organisms in a lake was demonstrated by a study whereby a small lake was experimentally acidified from an original pH value of 6.8 down to 5.0 over an eight-year period. PCA Ex. 98. This study (referred to as the "Schindler" study) is very helpful to understanding pH sensitivities because it was done "in the field", where natural responses of a variety of species could be observed.

At average pH of 5.93, several key organisms in the food web were severely affected. The opossum shrimp declined to only a few animals, and the fathead minnow failed to reproduce. Id., p. 1396. Tr. 13, p. 90. The fathead minnow was the major food source for adult trout, and the opossum shrimp was the major food source for young trout. Id.

At average pH values of 5.64, a species of filamentous algae with a foul odor formed in thick green mats. Crayfish eggs were found with fungal infections and their exoskeletons did not harden normally, indicating an inhibition of the recalcification process. Tr. 13, p. 92.

At average pH values of 5.1, spawning behavior of lake trout changed, partly due to the invasion of algae into previous spawning sites. No fish species were observed to reproduce at pH levels of 5.0 to 5.1. Crayfish populations declined to near extinction. Adult fish grew normally, and survival rates were constant, but their condition (an indicator of fish health) was clearly poorer than observed at higher pH values. Tr. 13, pp. 99-103; PCA Ex. 98, p. 1398.

93. The existence or absence of adult fish are poor indicators of stress from lake acidification. Older fish will often be able to survive even though they cannot reproduce. The most valuable biota, as early indicators of pH damage, are specifies with short life spans, where the bulk of the reproductive population is made up of one or two year classes. CEO Ex. 8, p. 15; Tr. 13, p. 102. Benthic crustaceans, such as the oppossum shrimp and fathead minnows are very sensitive species and serve as good indicators of acid stress. Sharp reduction in populations of both these species occur at pH 5.93, and have been reported to disappear at pH levels as high 5.8. CEO Ex. 8, p. 12 and PCA Ex. 98, p. 1396. Another good indicator of acid stress is the presence of filamentous algal mats at approximately pH 5.6. CEO Ex. 8, p. 13.

As species decline upon acidification, other species populations frequently increase in response. This phenomenon has been observed in the case of the fathead minnow. Minnow populations started to decline at about pH 5.8, but a consequent rise in the population of the pearl dace was observed. Tr. 14, p. 54, and Tr. 13, p. 91. As acidification continues, fish reproduction ceases, indicating that severe acidification will thwart the compensating effect of niche ecology.

Biologic damage due to pH declines might also be attributable to the additional toxicity of trace metals. This will be covered in a separate section on trace metals.

There is no conclusive evidence that the indirect effects of lake acidification, such as changes in food availability or types, will cause significant changes in fish community structure or biomass before the combined direct effects of low pH and elevated trace metal concentrations disrupt the fisheries. NSP Ex. 257, p. 2. The importance of the experiment described above is that it illustrated the sensitivity of a variety of organisms to increasing acidity. Focusing only on adult game fish masks important impacts at more moderate pHs.

Trace Metals

94. metal ions become more soluble in aqueous solutions as the acidity of the solution increases. PCA Ex. 47. Acidification of surface waters can lead to higher metal concentrations in the aqueous environment and to elevated concentrations of metals in the biota of an aquatic system. However, conclusive studies identifying a pH threshold where damage begins occurring are not available. SONAR, p. 81 and Tr. 17, p. 9. The deposition, mobilization and bioaccumulation of trace metals was not directly addressed by the MPCA in setting the proposed deposition standard. SONAR, p. 299.

95. Several metals can be mobilized through acidification, including

aluminum, calcium, copper, iron, lead, mercury and zinc. Of these, calcium, copper, iron, and zinc are essential elements to life and are generally toxic only at very high levels. The remaining elements, aluminum, lead and mercury can be toxic at much lower levels and warrant closer consideration. PCA Ex. 89, p. 599.

96. Aluminum can be toxic to fish at low concentrations. NSP Ex. 257, p. 21. Solubility of aluminum is low at pH 6.0, but its solubility increases rapidly as the pH drops to around 5.5. Tr. 13, p. 240. Conversely, as pH is

raised from 5.0 to 6.5, all aluminum will precipitate out of solution. Tr. 13, p. 242. Thus, at pH approximately 5.8, where damage to biological indicators of pH stress is observed, aluminum is just beginning to become soluble.

An apparent problem with measuring aluminum toxicity is speciation of aluminum, which is extremely important to the response of fish to aluminum toxicity from acidification. Tr. 19, p. 84. Reports indicate that the presence of total aluminum increases as pH declines below 6.0, but the most toxic form of aluminum, which is trivalent aluminum, usually represents a smaller fraction of the total aluminum measured. Tr. 13, pp. 240-241.

Accurate measurement of aluminum toxicity is also complicated by the presence of dissolved organics in lake water. Inorganic aliminum compounds are the most toxic to aquatic organisms. Tr. 19, p. 85. Generally, brown water lakes will not exhibit the degree of toxicity to high aluminum and low pH as will clear lakes due to aluminum complexation by dissolved organic materials. NSP Ex. 257, p. 23. The higher the organic concentrations in lake water, the greater proportion of aluminum will be bound up in the organic, non-toxic form. Tr. 19, p. 84. In clear water systems, where there are low organic carbon concentrations coupled with low pH, there is a strong tendency for aluminum to be toxic to aquatic organisms. Tr. 19, p. 85. In New York, sensitive lakes are around pH 4.0 and sulfate is the dominate anion, while organic anions make up only 10 to 20% of the overall ionic concentration distributions. In Minnesota, the sulfate anion represents only about 20 to 25% of the anionic distribution while the organic ions are the dominate anions. The lowest pH values in the sensitive Minnesota lakes are around pH 5.5. Tr. 19, p. 105.

Minnesota's sensitive lake areas have high organic anion levels and it is uncertain how much buffering they provide at low pH or the degree to which they tie up aluminum in the non-toxic form. Information is not complete regarding how much of a role organics play in reducing the toxicity of aluminum, but the comparatively low levels of aluminum and high levels of dissolved organics relative to the Adirondacks, suggests that Minnesota aquatic organisms are less susceptible to aluminum toxicity than believed. Tr, 19, p. 107.

97. A change in acidity of water as a result of acidic deposition could affect the speciation of lead in water. PCA Ex. 89, p. 611. There is,

however, no evidence that lead undergoes a biomagnification in the aquatic food chain. PCA Ex. 89, p. 613. No studies have been reported on the effects of pH on accumulation of lead in aquatic food.

98. The dynamics of mercury chemistry and bioaccumulation in fish has been extensively studied, but conclusive data regarding at what pH mercury mobilization occurs or how and at what pH acidification influences mercury specification is not available. PCA Ex. 87, p. 13; SONAR, p. 82.

Mercury cycles naturally through the atmosphere as part of the hydrologic cycle of water but it is generally agreed that the sources of acute mercury contamination are from industrial usage and direct discharge into watersheds and the atmosphere. PCA Ex. 343, p. 38. Emissions of mercury from fossil fuel combustion are significant and add 1,000 kg of mercury per year, on the average, to the atmosphere from each 1,000 megawatt coal-fired steam electric plant. PCA Ex. 343, P. 38.

Mercury exists in a variety of physical and chemical forms. Of particular concern is the monomethyl mercury (hereinafter "methyl mercury") compound, because it is very readily accumulated by biota. Uptake of methyl mercury occurs via direct absorption from water across the gill as well as by intake in food. PCA Ex. 89, pp. 600-602.

As lake waters become acidified by sulfate deposition, the microorganism desulfubrio becomes the predominant species in sediments. This microorganism is very proficient at reducing sulfate in water to sulfide. The sulfide produced combines with and precipitates out many metals, including mercury, which tend to be more available in the water column due to the acidic conditions in the lake waters. These sulfide-metal complexes are then stored in the sediments, generally unavailable to biological uptake. Tr. 20, p. 17.

Methyl mercury is released into the water column only when all the available sulfate has been reduced to sulfide. At this point, the desulfubrio bacteria begins biomethylating mercury and other metalloids, and releasing methyl mercury and other metals into the water column. Tr. 20, pp. 17-18. Once methyl mercury is released into the water column, it is rapidly distributed among all the biota in the lake.

Thus, where sulfate reduction is occurring in a lake, the byproduct of this reaction tends to tie up mercury in the sediments and only when the supply of sulfate is depleted will biomethylation occur.

99. Bioaccumulation of mercury in fish has been documented in Minnesota. PCA Ex. 94. This study indicates that, although fish advisories were issued for several of the lakes sampled, mercury concentrations in the water and in the fish tissue are not likely to be deleterious to fish survival. Fish-eating birds and other fish-eating wildlife may potentially suffer harmful effects, however. SONAR, p. 194. Analysis of the lake study data suggests a relationship between low alkalinity, low pH, and elevated concentrations of mercury in fish tissue.

Precipitation Chemistry

100. Maintaining a precipitation pH of 4.7 is a reasonable goal, and it was not seriously criticized in the record. Instead, criticism was directed at the translation from a precipitation pH of 4.7 to the 11 kg/ha/yr wet sulfate standard. That translation is the subject of precipitation chemistry. The chemistry of precipitation is highly unstable and is affected

by many factors. As a result, calculating ionic correlations in precipitation for determining how much acidity is associated with a specific ion is a difficult process. Precipitation data used in chemical and mathematical calculations must meet the constraints of statistical validity before inferences or predictions can be drawn.

101. The pH of rainfall in remote, pristine areas is not neutral. Natural sources of acidity exist in the environment. In pristine areas, the pH of precipitation in the absence of anthropogenic influences falls around pH 5.0. Tr. 7, p. 244; Tr. 28, pp. 271-278. Natural organic acids comprise much

of the acidity in pristine environments. NSP Ex. 182. Estimations of the natural pH level of precipitation based purely on calculations of equilibriums of atmospheric carbon dioxide with precipitation, fall at or about pH 5.6. SONAR, p. 22. However, precipitation pH In nonarid, remote areas often averages 0.3 - 0.5 pH units lower, or more acidic, due to the presence of trace substances in the atmosphere incorporated into precipitation. PCA Ex. 211, p. 2.

102. Differences in pH, although expressed in straight numerical relations, are not linear. The pH scale is logarithmic. A pH of 3 is ten times more acidic than a pH of 4, 100 times more acidic than pH 5, and 1,000 times more acidic than a pH of 6. PCA Ex. 76, p. 5. Therefore, small differences in pH represent much larger differences in hydrogen ion concentration than the absolute numbers indicate.

103. Deposition occurs through both wet deposition (rain and snowfall) and dry deposition. Dry deposition occurs in the absence of precipitation, and field measurements are extremely difficult to obtain accurately. NSP Ex. 322, p. 129. To date, attempts at collection of dry deposition data have largely been useless. Tr. 17, p. 4. Several factors influence the amount and effect of dry deposition, such as distance from source, type of surface deposited on, wind and moisture. PCA Ex. 178.

Generally, dry deposition comprises the majority of total deposition at or near major emissions sources, while wet deposition accounts for the largest portion of total deposition at long distances from the sources. PCA Ex. 172, p. 274; NSP Ex. 322, p. 129.

Chemical analysis of precipitation events is only of the wet deposition fraction, but the data provides for a partial estimation of total loadings. Wet deposition is used as a surrogate for total deposition. Curtailment of wet deposition as a means of emissions control will correspondingly decrease the dry deposition component, although the precise amount will never be known. PCA Ex. 178.8.

104. In general, precipitation is a very dilute, highly unstable system. Tr. 7, P. 186. As particles are emitted into the air, they collect water vapor particles, which coalesce to form clouds made up of water vapor and particles, some of which are pollutants. Tr. 7, p. 182.

Wet deposition contains several major soluble species, including the following ions: hydrogen, bicarbonate, magnesium, sodium, potassium, sulfate, nitrate, chloride and ammonium. These ions comprise the majority of elements affecting pH in wet deposition. NSP Ex. 322, p. 130. Certain exceptions exist, however, such as at remote "pristine" locations where organic acids can have a significant effect on the pH of the system. Id. Organic acids may affect the pH of a precipitation sample, but, because organic acids are rapidly assimilated by the biota, they are unimportant in the acidification of the environment. Tr. 28, p. 287. The chemistry of organic acids and how they interact with other compounds in the environment is not well understood. Organics play a more important, but not clearly defined, role in lake water chemistry than in precipitation. See discussion on "Aquatic Sensitivity," above.

105. In order to analyze precipitation chemically, precipitation samples were collected at various sites across the state. Specifically, precipitation chemistry data from 17 sites in three different monitoring networks were obtained. The largest of the three networks, the National Atmospheric Deposition Program (NADP) operates weekly collection, wet-only precipitation samplers throughout the United States. The Multistate Atmospheric Power Production Pollution Study (MAP3S) collects event samples in the northeast and midwest United States. Finally, the Minnesota-Wisconsin Power Suppliers Group (Min-Wis) collects refrigerated, sequential fractions within events at sites in Minnesota and Wisconsin. PCA Ex. 211, pp. 3-4.

The samplers from the Min-His monitoring system were used only from April through October, making annual deposition analysis possible only through extrapolation. All long-term monitoring networks in Minnesota utilize a wet-only automatic collector which allows the precipitation collection bucket to be exposed to the atmosphere only when precipitation is falling. SONAR p. 269.

106. Analysis of precipitation chemistry data can be difficult because of the differences between field-measured pH and laboratory-measured pH. It is well known that the pH of a sample measured in the field at the time of sample collection is usually somewhat lower than the corresponding value for the same sample measured days, or weeks, later in the laboratory. SONAR p. 290. This is primarily attributable to transient chemical conditions in field precipitation samples, and laboratory pH is regarded as the better measure for evaluating effects. Id.

107. The precipitation chemistry data expresses ionic deposition on a volume-weighted basis. Volume weighted concentration is an integration over time of the final concentration of a substance that would be measured in a container if evaporation and chemical modification did not occur prior to measurement. NSP. Ex. 147, pp. 3-8. The value represents an average value that has been calculated over all events, without taking into account the amount of precipitation falling on an event-by-event basis.

For purposes of modeling the deposition of any particular ion in Minnesota, the precipitation rate in the sensitive areas was calculated to be an annual average of 70 centimeters. SONAR, pp. 5, 292. Volume is an important parameter, and it is dangerous to compare data from Minnesota with data from other parts of the world that has a different volume basis.

108. The ionic composition of precipitation anywhere in the world is

basically the same. Tr. 28, p. 293. Variations between sites occur primarily due to differences in percentage composition of the major elements in relation to each other. PCA Ex. 414, p. 2. Variations in deposition is also strongly associated with the amount (volume) of precipitation. Tr. 28, p. 302.

The major ions in precipitation are composed of positively charged cations and negatively charged anions which bond together to form a large array of compounds. Special importance is placed on those compounds which have acid-forming capacity. PCA Ex. 414, p. 4.

109. Sulfate is the primary carrier of strong acid which acidifies surface waters through atmospheric deposition. Tr. 29, p. 27. Consequently, the combination of sulfate and hydrogen forms the primary acidifying compound

in precipitation, sulfuric acid. However, sulfuric acid is not the only acid-forming compound. Other elements, such as ammonium, can bind with sulfate in precipitation without an apparent acidifying effect. However, when ammonium sulfate reaches the ground, it dissociates and ammonium Is taken up by plants, releasing hydrogen ions, and therefore resulting in acid in the environment. PCA Ex. 414, p. 5 and Tr. 29, p. 48.

To a smaller degree, acids formed from nitrate also contribute to acidification, but this effect may be largely offset by the fact that nitrogen acts as a limiting nutrient that is readily taken up by plants for growth. NSP Ex. 17, p. 8. Plant uptake of nitrate tends to add alkalinity to a system, and therefore the acidifying effect of nitrate is not of great importance. PCA Ex. 414, p. 5.

110. The upper midwest region has a distinct depositional gradient from west to east. PCA Ex. 341, p. 3. This gradient extends from northeastern Minnesota, where the volume weighted average pH of precipitation is 4.8-4.9, to north central Wisconsin where the pH precipitation is 4.6, and finally to the eastern portion of the upper peninsula of Michigan, where the pH of precipitation is 4.3-4.4. PCA Ex. 341, pp. 3-4.

In the eastern United States, where precipitation pH values are lower, studies show that hydrogen ion deposition and sulfate deposition are closely correlated. SONAR, p. 275; NSP Ex. 147, pp. 3-9. In that region, the relationship between acidity and sulfate is approximately linear. Tr. 4, p. 9. However, in Minnesota, sulfate deposition levels are lower and are not neatly correlated with hydrogen ion deposition. NSP Ex. 147, pp. 3-8.

Precipitation data from Minnesota shows a wide range of sulfate deposition concentrations in precipitation samples with pH greater than 5.5. Certain elements neutralize acids in precipitation. Calcium is one of the predominant neutralizing substances and, in general, where calcium deposition is high the pH will tend to be higher. Tr. 4, b. 27. Minnesota is blessed with substantial quantities of calcium, especially in the southwest and western portions of the state. The presence of greater amounts of these neutralizing substances in Minnesota precipitation may explain the high sulfate, high pH events which are more common here than those in the eastern U.S.

111. Precipitation chemistry involves many complex ionic correlations, some of which tend towards acidity, and others which don't. Because hydrogen and sulfate do not strongly correlate with each other in Minnesota (SONAR, pp. 274-275), studies to quantify the percentage of anions in precipitation that are not associated with hydrogen (non-acid anions) have been conducted. For eastern wet-fall sites, the amount of non-acid anions ranged from 6% to 54%. Wet-fall sites in Minnesota, South Dakota, and Nebraska showed that precipitation contained greater than 71% non-acid anions. NSP Ex. 147, pp.

3-15. These estimates failed to account for other anions, such as organics, which could be associated with hydrogen in precipitation and which would reduce the percentage estimate of sulfate, nitrate and chloride associated with hydrogen. Id. This study is another method of exhibiting the fact that more sulfate falls in the form of sulfuric acid in the eastern United States than in Minnesota.

1 1 2 . In an attempt to quantify the relationship between acidity of precipitation and the concentration of sulfate in precipitation, the statistical method of regression analysis was applied. SONAR, p. 292.

A fundamental condition to the use of any regression analysis is that the results obtained from the regression must be tested for their statistical significance. Tr. 4, p. 102. Statistical significance can be expressed as having varying levels of confidence. The higher the confidence level, the higher the statistical significance.

In order to test a regression analysis for statistical significance, certain conditions must be met. One basic condition is that the data be normally distributed, or that the variables used are assumed, when using regression analysis, to be normally distributed. Tr. 4, pp. 103, 138. A second assumption is that the residuals, the difference between an observed value and a value predicted by a model or equation, are also normally distributed. NSP Ex. 104; Tr. 4, p. 38. A third assumption in statistical analysis is that the variances between the observed population and the predicted values from the equation be equally distributed, or "homoscedastic". Tr. 6, pp. 55-56; NSP Ex. 116. Also, the residuals must be independent. Tr. 4, p. 139.

If any of these fundamental conditions are significantly violated, any statistical predictions or inferences from the regression analyses are invalid. NSP Ex. 131. There seems to be some evidence, however, that regression techniques are relied upon, to a certain extent, even though the variables used are not normally distributed. The degree to which a data set is not homoscedastic and therefore technically unreliable, is a judgment call. Tr. 4, pp. 103, 139.

The residuals of the regression models used by the agency were not normally cistributed, rendering a statistical inference from the analysis suspect. Tr. 6, P. 166.

113. A standard statistical technique used when a data set appears to be not normally distributed is to take the logarithm of the non-normal variable and test for lognormal distribution. PCA Ex. 211, p. 5. Expression of data in the log form, rather than the ionic concentration form, does not change the data -- it only changes the manner in which it is expressed. Tr. 4, p. 107. The log transformations of the ion concentrations used by the agency in its multiple regression analyses do appear to be lognormally distributed. Tr. 4, P. 105.

114. Several approaches were used by the agency to quantify the

relationship between acidity in precipitation and sulfate concentration in precipitation. The goal was to determine what level of sulfate was associated with a precipitation pH of 4.7. The large natural variability in precipitation chemistry results in some methods working well to relate certain ions in a geographical area, while the same method may be inapplicable in a different area. No single method of analysis is universally applicable for relating ion concentrations and acidity. PCA Ex. 211, p. 3. Several approaches were used by the agency to support its proposed deposition standard of 11 kg/ha/yr.

115. The chemical balance approach is based on the theoretical presumption that, for a given pH value, all hydrogen ions are associated with sulfate. A set of six equations was developed, each one attempting to account for the effects certain ions (or combinations of ions) would have on the basic acidifying effect of sulfate on precipitation. Each equation was then used to calculate sulfate acidifying potential, based on actual NADP data. Tr. 4, p. 79; SONAR, p. 298.

This approach presents generalized background information regarding ionic relationships, but does not provide a basis for a theoretical or empirical explanation for the sulfate deposition standard proposed.

116. The multiple regression technique treats one ion as a dependent variable, and uses other ions as independent variables. The regression technique then calculates the concentrations of the dependent variable, using the independent variables as predictors. Two multiple regression formulas were used, one with sulfate as the dependent variable, and calcium, magnesium, ammonium and hydrogen as independent predictor variables. The second regression equation used pH as the dependent variable, with calcium, magnesium, ammonium, sulfate and sodium as the independent, predictor variables. Due to non-normal distribution in the data set of the ions used as independent variables, the log transformation of each ion was used in each equation. SONAR, pp. 294-295.

117. The first equation was found to be statistically significant, and, in theory, calcium, magnesium, ammonia and hydrogen accounted for 73% of the variability of the sulfate ion concentration. In other words, under this equation, only 27% of the variability of sulfate ion concentration was associated with other substances. This first equation does not include nitrate as an independent variable.

118. The second multiple regression equation used by the agency to relate acidity and the components of precipitation was one using pH as the dependent variable. The best regression equation which could be established accounted for only 51% of the variability in the pH. Tr. 4, p. 133. This relatively poor result was inconsistent with the first equation using sulfate as the dependent variable, and could be explained by the presence of other substances, such as bicarbonate and organic acids, which influence pH but were not included in the equation. The poor correlation from this second equation rendered it unsuitable for relating effects levels to deposition (SONAR, p. 295), because it incorrectly and unreasonably attributed much of the variability in pH to the sulfate ion, therefore resulting in an unexpectedly

high value. Tr. 4, p. 136.

For each of these equations, the actual average concentrations for the independent variables from NADP and MPCA precipitation chemistry data were substituted in the equation and the equation was then simplified into an equation relating acidity and sulfate concentration, taking into account the average deposition of neutralizing cations. From the equation using sulfate as the dependent variable, the secondary equation generated predicts, using actual precipitation chemistry data, that sulfate deposition rate of 11.5 kg/ha/yr corresponds to the effects threshold pH of 4.7. SONAR, p. 294.

119. The final technique used by the agency for relating deposition to effects levels is an empirical model of the relationship between sulfate and hydrogen by using non-linear regression (the curvilinear technique). When the variables considered are present in a non-linear relationship, a common statistical method is to use a polynomial equation to describe the curve. PCA Ex. 211, p. 5. When used to relate sulfate and hydrogen ion concentrations from Minnesota precipitation chemistry data, the curvilinear regression equation predicts a sulfate deposition of 10.8 kg/ha/yr, plus or minus 0.7 kg/ha/yr from the effects threshold pH of 4.7. SONAR, p. 296. The reliability of this result is supported by high statistical significance of the model as a whole and the terms used, and because of the low standard errors of the model coefficients. Id.

A major problem with the statistical results from this method is the low coefficient of determination (r2) reported, .20, which means that the model only explains 20% of the variability of the data. This low coefficient of determination may be a reflection of the high variability in the data and the inaccuracies in the measurement of sulfate and acidity. Id.

The variability in the data sought to be expressed by this curvilinear technique is clearly shown by PCA Ex. 147, p. 9, which is a graph of the curvilinear relationship between sulfate and acidity. A general curve is indicated, but, at pH values of 5.5 and above, the sulfate concentrations tend to be highly variable, indicating that Minnesota receives high pH precipitation that varies in sulfate content. The curvilinear plot suggests that two precipitation events may occur in Minnesota -- one that is low pH and high sulfate, the other that is high pH and high sulfate. This phenomenon may be of concern when a deposition standard is implemented on the assumption that high sulfate deposition corresponds with low pH. It is apparent that high sulfate deposition can occur with high pH. Such an event could violate the deposition standard, but would pose no threat of acidification because of the high pH.

The graph of the curvilinear regression technique, PCA Ex. 147, p. 9, shows many of rainfall events at high pHs with high sulfate concentrations. This is a warning that the relationships between hydrogen and sulfate in Minnesota are not linear, as they are in New York. Therefore, we should be careful not the adopt New York standards as applicable in Minnesota.

Summary of the Proposed Standard's Pros and Cons

120. Many of the models used by the PCA in determining the standard relied on statistical methods in analyzing the data. As was discussed, those methods require that the data meet certain statistical assumptions. The data relied upon by the PCA failed to pass the initial statistical tests for

validity.

121. The Schnoor trickle-down-model simulated 50-year runs with progressively greater sulfate deposition rates. The ultimate conclusion reached by those model runs indicated that when precipitation pH reaches 4.7, lakes will lose all of their alkalinity and the pH of the lakes will drop to approximately 5.0. This finding is one of the major benchmarks upon which the 11 kg/ha/yr standard is based. One difficulty with characterizing a lake as acidified at pH 5.0 is the finding by Dr. Schindler that lake biota such as

shrimp and minnows are affected at pHs as high as 5.8. This fact, standing alone, tends to support 11 kg/ha/yr as the right number, or maybe even a lower number.

122. One of the characteristics emphasized by Dr. Driscoll for Minnesota lakes is that some have high dissolved organic carbon. The presence of organic acids in lake waters tends to lower the pH of lakes, but the low pH from these organic acids is not reflective of the sulfuric acid problem. Organic acids have an optimum buffering capacity at or around pH 4.5 to 5.0. SONAR, p. 178. If a deposition standard is set at a number higher than 11, there is a possibility that the pH of the lakes will decrease over time to pH levels in the high 4s and the buffering from organics will become important at those levels. However, those levels are far below those which would exhibit adverse effects upon aquatic biota. In summary, there is just not enough known about organics and their effects upon acidification at this time to rely upon them to buffer acidity.

123. The 16 kg/ha/yr standard advocated by NSP and MP Is based on the ILWAS model run on Meander Lake. Meander Lake is not truly a seepage lake in that it has inlets and outlets and those inlets carry basic cations from the watershed. Therefore, Meander Lake is far from the most sensitive lake in Minnesota. If the 16 kg/ha/yr standard were adopted, critically sensitive lakes may acidify.

124. The 41 critically sensitive lakes discussed earlier all have less than 40 micro equivalents per liter alkalinity. 37 of them already have pHs of less than 6.0 This is important because of the pH levels at which aquatic biota are affected. Setting a standard that allows for any substantial acidification may adversely affect these lakes.

125. In summary. the major points suggesting that 11 kg/ha/yr is too strict, and unreasonable, are:

a. Statistical problems. The data relied upon by the PCA was non-normal and there is no strong linear relationship between sulfate and hydrogen in Minnesota;
b. Modeling deficiencies. None of the models relied upon by the PCA included or quantified the alkalinity-generating process of sulfate reduction that goes on in a lake;
c. Data problems. The NADP data relied upon by the PCA was collected weekly and not refrigerated, thereby possibly skewing the effects that organics may have on the precipitation. Also, there are issues of the proper use of volume weighted averages and the pooling of non-homogenous data for setting the standard; and
d. Organics. The issue of organics and organic acids occurring naturally in lakes were largely ignored by the models used by the PCA. This was not because of ignorance but because there is a lack of scientific consensus on the

effect and the degree of impact organics have on acid deposition.

Some of the major points in support of an 11 kg/ha/yr standard are:

a. Ammonium. The pH of rainfall does not measure the additional acidifying affect of ammonium in rainfall. Ammonium sulfate does not affect the pH as measured, but when it hits the ground, ammonium is taken up by plants and releases a hydrogen ion creating an acidifying effect. Most of the equations used by the PCA shown on page 298 of SONAR do include ammonium in their equation for converting pH of rainfall to acidic sulfate deposition.;

b. Schindler study. Aquatic biota are affected at pHs slightly below 6. This is a major point in light of the fact that the Schnoor trickle-down theory was calibrated to protect a lake from acidifying below 5. If the aquatic biota and the food chain in a lake will be seriously affected at pH levels much higher than this, it supports a deposition standard at or below 11;

c. Buffering. Sulfate reduction efficiencies vary from lake-to-lake. None are 100% efficient. Over time, the sulfate reduction process can be overwhelmed and any additional deposition of sulfate will create acidification;

d. Statistics. The fact that the data base relied upon by the PCA does not exhibit statistically normal distribution is not fatal. Natural data is rarely normal, and reasonable inferences from non-normal data are commonly made;

e. Sensitive Resources. Some resources were not included as sensitive by the PCA. These resources include wetlands and poor fens (peat lands) which may have been improperly excluded. Also, lakes less than ten acres in size were not included in the data base. These lakes may be the most sensitive of all.

126. It is found and concluded that the 11 Kg/ha/yr annual wet standard is within the range of reasonableness established by this record. However, it may be on the lower ("StriCtH) end. The fact that Minnesota precipitation is quite different than that seen in New York or Scandinavia indicates that Minnesota may not be as sensitive as those areas. Notwithstanding the fact that the Agency's models failed to account for in-lake buffering and sulfate reduction or the fact that organics and their effect on acidification were not factored into the standard does not render the it unreasonable. None of those processes can be scientifically quantified with a high degree of certainty, and they can be properly viewed as offsetting some of the fears raised by the Schindler study discussed above.

Long-Range Transport

127. The area of heaviest sulfate deposition and acid precipitation in the United States is in and downwind of the chief coal-burning states of Ohio,

Indiana and Illinois, which together produce approximately 1/4 of the total United States emissions of sulfur oxide and 1/6 of the total emissions of nitrogen oxide. PCA Ex. 7.

128. on a state level, Minnesota sources account for approximately 10% of Minnesota's wet sulfate. Specifically, in 1982 the MPCA estimates that between 3 and 16% of wet sulfate deposition came from instate sources; NSP estimates 10%. The average of all available figures is 12%. There is no question but that Minnesota is a net importer of acidic deposition. The other 88-90% comes from Texas, Missouri, Wisconsin and some Canadian provinces. Tr. 1, pp. 69-70. The data shows some variation from year to year site to site. While the list of the top ten sources remains fairly stable, the order of those sources varies from one site in Minnesota to another. Texas is high all over Minnesota, usually one of the highest states of all. SONAR, pp. 511-512. Deposition levels decrease as one moves from southeast Minnesota to northwest Minnesota, in clearly defined gradients. MP Ex. 3, p. 2.

129. Over 50% of all the sulfur dioxide emitted in Minnesota in 1980 came from six sources, with over 70% of the state's total sulfur dioxide coming from eleven sources. Of these eleven, nine are power plants, and two are refineries. SONAR, pp. 305, 314. Almost one-half of Minnesota's sulfur dioxide emissions are from the heavily populated five-county metropolitan area. The only out-state counties that show comparable emissions are Sherburne County and Itasca County, the sites of two of the state's largest power plants. SONAR, p. 312.

130. Minnesota's sulfur dioxide emissions are decreasing despite the fact that generation is increasing. In 1978, total emissions were approximately 265,000 tons per year. (hereinafter "TPY"), of which approximately 190,000 tons were from utilities. In 1982, total emissions had dropped to approximately 190,000 TPY, of which 128,000 tons were from utilities. SONAR, p. 311 and MP Ex. 3, p. 11. The primary reasons for these decreases are fuel-switching, scrubber installations, economic recession, and plants operating at less-than-full capacity.

131. More than 90% of the sulfur emitted by man is released as sulfur dioxide. The rest is released as sulfate or sulfur trioxide. Sulfur dioxide is transformed into sulfuric acid. MPCA Ex. 239. in the atmosphere, mixing occurs between sulfuric acid, nitric acid and in some places, hydrochloric acid. Through oxidation, the sulfuric and nitric acid become sulfate and nitrate, which are the acidic components of acid deposition.

Anthropogenic emissions come from point sources such as heating units, small combustion sources and mobile sources. NSP Ex. 262, p. 76. Other sources are power plants, industrial plants, and homes. Most sulfur dioxide is emitted from power plants and most nitrogen oxide is emitted from mobile sources. SONAR, p. 312. In 1980-84, more than 60% of Minresota's sulfur dioxide was emitted from electric power plants, while 30% came from other industrial sources. SONAR, p. 541. Sulfur oxide emissions come mainly from urbanized areas. The same can be said of nitrogen oxide and hydrocarbon emissions. NSP Ex. 262, p. 69.

Natural emission sources include biogenic sources, geological /sources (volcanos, natural gas seeps and geysers) and fugitive dust and soil

particles, especially in the southern and western parts of Minnesota. NSP Ex.
262, p. 76.

132. Long-range transport of anthropogenic and natural emissions, as well as short-range transport, has been documented. Emissions from one state or country flow into the upper atmosphere and are transported to another state or country, where they are deposited. As a consequence, some areas of the United States and Canada produce and expel many pollutants, while others mostly receive pollutants.

133. Long-range transport involves several steps. First is source emissions, which have been discussed above. The next step is transport. Pollutants are emitted into the mixed layer, the lowest layer of the atmosphere. This mixed layer exhibits a diurnal cycle; there is much intermixing of pollutants and oxygen during the early afternoon, and almost none in the night time. Therefore, if pollutants are released above the mixed layer, at night, they travel a long way with virtually no mixing. Pollutants will eventually intersect the mixed layer at some point downwind (at the receptor site) and become well mixed. MPCA Ex. 240, p. 3-2.

Wind determines transport. Wind patterns vary from microscale eddies to mesoscale circulation patterns to synoptic weather patterns to planetary-scale waves that influence weather patterns around the globe. NSP Ex. 262, p. 4. Depending upon meteorological conditions, once a pollutant is emitted, it may travel long distances.

A third step is transformation, i.e., chemical transformation. Precipitation acidity is, as mentioned, primarily associated with the sulfate and nitrate ions. The transformation from sulfur dioxide to sulfate, and from nitrogen oxide to nitrate, is complex and dependent upon a number of variables. See, NSP Ex. 262, pp. 9-16. They were not contested, and will not be discussed further.

The last step is deposition, or the movement of pollutants from the boundary layer to the earth's atmosphere. In general, the pollutant flows down from the boundary layer, is transported across the quasi-laminar layer and then interacts with the surface.

134. Dry deposition is not as easily analyzed, or modeled, as wet deposition. Acknowledging this, the proposed 11/kg/ha/yr standard is for wet deposition, but is based on a dry deposition rate of about 4 to 5/kg/ha/yr. SONAR, p. 6.

135. In summer, there is much oxidant formation of acids from urban sources. In the winter, however, the rate is curtailed.

Also in summer, thunderstorms of either the air mass type of the frontal type occur. The frontal type thunderstorm is very important in depositing pollutants, because in advance of the storm front southerly winds, warm temperatures and high humidity are found -- all of which raise the oxidation rate. Tr. 18A, pp. 25-26.

136. The potential for pollutant formation acts in the opposite sense from the climate; low ventilation coefficients during the winter enhance the buildup of primary pollutants (nitrogen oxide and sulfur dioxide), but low

transformation rates inhibit the buildup of the secondary pollutants (sulfate and nitrate). On the other hand, summer enhances the formation of the secondary pollutants. NSP Ex. 262, p. 65.

137. The long range transport modeling can be summarized as follows:

a. The results of both the Agency and NSP models show that Minnesota produces minimal amounts of sulfate and nitrate deposition within the state. Minnesota imports approximately 88-92% of the components that comprise acid deposition.

b. The ESEERCO model and the MESOPUFF II model measured wet sulfur deposition (sulfur dioxide plus sulfate), while the RTM-NSP model measured wet sulfate. There is no information available to determine if the Agency's predictions are similarly apportioned between sulfur dioxide and sulfate wet deposition. Further, the Agency evaluated wet deposition at only two Minnesota sites. The RTM-NSP model evaluated wet deposition from many more receptors.

c. The Agency's models were not able to handle non-linearity. Oxidation of sulfur dioxide to sulfate is inherently non-linear.

d. The hybrid nested-grid Eulerian model is superior to the pure Lagrangian trajectory model because it combines the puff trajectory technique with the grid technique to simulate horizontal and vertical transport. The model results are more complete than the results of a Lagrangian model.

CONTROL PLAN

138. The only monitoring station in Minnesota which does not now meet the proposed 11 kg/ha/yr standard is at Sandstone. While there are probably other locations in the state where the standard is not being met, they are unknown because monitoring has only occurred at a limited number of locations.

The contribution of major sources to deposition at Sandstone is as follows:

CULPABILITY (Sandstone, 1980)

MP-Boswell	.009 kg/ha/yr	.0299%
NSP-Sherco	.069 kg/ha/yr	2.269
NSP-King	.046 kg/ha/yr	1.502
All Other Minnesota Sources		3.530
Total		
Minnesota Sources		7.600%
Out of State Sources		92.400

(SONAR, pp. 525-563).

139. As can be seen from the above, Minnesota sources only contributed approximately 7.6% of the deposition at Sandstone in 1980. The vast majority of the deposition, about 92%, came from outside Minnesota. Looking at Minnesota sources, Sherco is the largest and King is the second largest. All other point sources (including Boswell) contributed less than .5% each (SONAR, p. 563) to the Minnesota total deposition at Sandstone. MP Ex. 3; Tr. 3, pp. 115-116; Tr. 19, pp. 8 & 28; NSP Ex. 265.

140. Despite these small percentages, it is reasonable to seek reductions from in-state sources. The control plan requires reductions from Minnesota's two largest electric utilities, since this will be the most cost-effective means of achieving these reductions. Large electric utilities in Minnesota emit over 50% of the total S02 in the state (SONAR, pp. 305 & 387) while accounting for 85% of the modeled wet deposition at Sandstone from Minnesota sources (Id., P. 587). Minnesota Power and Northern States Power account for over 60% of all emissions from large utilities in the state, and 1/3 of the total sulfur dioxide emission in the state. Id., pp. 567 and 323. It cannot be said that the control plan is unreasonable because it seeks to regulate these two large sources. However, the small contributions from in-state sources make it abundantly clear that reductions in Minnesota are inadequate to attain compliance with the standard.

National Legislation

141. The National Governor's Association has proposed an acid deposition control plan. This plan is a representative model of proposed national legislation which can be used to determine in-state control levels and Minnesota's "fair share" under potential regional and national programs.

An issue arose as to whether or not the proposed control plan is actually consistent with what is likely to finally become national legislation. This issue becomes difficult because of the uncertainty as to which, if any, of the currently proposed national legislation will be enacted. While there are a number of reasons to be concerned about national legislation (which is the only real solution to this problem), the question of whether Minnesotans would be forced to pay more than their fair share when legislation is finally passed is a matter of concern.

The Agency's control plan is consistent with what we know about proposed legislation at this time. The three most serious proposals before Congress include the Mitchell Bill, the Stafford Bill and H.R. 4567, the Sikorski/Waxman Bill. SONAR, p. 570. Two of these bills are based on 1980 emissions and would require Minnesota to reduce emissions by approximately 60,000 tons per year from those 1980 levels by 1997. The Agency's control plan would achieve that reduction. SONAR, p. 567.

Some bills, including the Sikorski/Waxman Bill, require an average emission limitation for all SO, sources in the state. This type of limitation does not control total emissions, only the rate at which emissions occur. The Sikorski Bill previously required a monthly statewide sulfur dioxide emission rate averaging less than 1.2 pounds Of S02/MM BTU. Recently, however, a House Subcommittee amended the bill to change the monthly averaging to annual averaging. MP Reply Brief, p. 7. The requirements of the original bill could not be achieved without the proposed control plan reductions. It is a very close question as to whether compliance with the newly amended bill could be achieved without the control plan. So long as Sherco 1 is operating, Minnesota would be just in compliance without the control plan. However, if Sherco I is out of service for any reason, then it Is likely that Minnesota would not be in compliance. But it is a close question, depending upon how long Sherco I is out of service, what plants are used to replace it, what the demand is at the time, etc.

142. The primary area of concern with regard to these national programs is the possibility of a "generation tax" which would be applied regardless of emission rates at a specific plant, on a specific system, or even statewide. In other words, regardless of whether the plant was extremely clean or very dirty, a tax would be charged upon its use based on the amount of electricity generated, not the pollution produced. The money raised by this tax would then be used to assist utilities with the installation of pollution prevention devices. If Minnesota were to require its utilities to make expenditures now, and if such a generation tax gave no credit for either clean emissions or past improvements, then Minnesota would be forced to pay more than its fair share.

There is no reason to believe that Minnesota will be required to pay twice for S02 reductions, unless the federal legislation incorporates a generation tax. Although national legislation is still largely uncertain, there is no reason to believe that the reductions under the proposed control plan will be more than Minnesota's fair share under an eventual national program.

143. The proposed control plan is both rational and reasonable in its approach to the promotion of a national program. There is a strong relationship between state action on acid deposition and the goal of enacting a national program. A national program for acid deposition control has been put off for decades on the basis that scientific evidence for control was not conclusive. Independent actions by states like Minnesota, especially when they generate a formal record such as this, demonstrate that the factual issues involving the source of acid deposition can be documented. Tr. 23, pp.

54-56. Minnesota's prior record and continuing actions in -educing emissions cuts it in a position to demand reductions from other states. Similarly, strong action by Minnesota will send a clear message to Washington and other states that we are willing to pay to protect our own environment, and to do so before asking others to act.

Regional Program

144- One of the most important concepts to emerge from this rulemaking proceeding is the fact that Minnesota is not the only state which is taking independent action at this time, and that a state can be influential at a regional, as well as a national level, through actions which promote cooperation between the states themselves. Tr. 26, pp. 90-91. The approach is already working on a regional basis. Minnesota seems to be part of an unintended regional strategy which is developing. Tr. 29, pp. 13-24. Minnesota was the first state in this area to pass acid deposition legislation. Minnesota's action served as an example to other states and has contributed, in part at least, to actions which have since been taken elsewhere. Minnesota's example was helpful in New York, for example, in that it indicated that it was possible for a state to take positive action without waiting for a federal program. Tr. 29, p. 6. Other states have responded as well. Wisconsin has enacted legislation which establishes a program intended to reduce SO, emissions by 50%. Tr. 23, p. 134. This will be done primarily by fuel switching, In addition, the states of New Hampshire, Massachusetts, and Michigan have all taken steps to reduce acid deposition. Tr. 29, pp. 18-20.

145. Two of these states, Wisconsin and Michigan, are among the top states responsible for deposition in Minnesota. SONAR, p. 564. The independent action taken by these states will prompt the national perception that there is a need for national acid deposition program. But more importantly, the independent action of states and provinces which significantly contribute to deposition in Minnesota may well bring faster results for Minnesota than a national program. It is this regional approach that goes a long way to offsetting the minimal contributions to Minnesota deposition from Minnesota sources.

Systemwide. Caps

146. Are the systemwide caps proposed for NSP and Minnesota Power so restrictive that the companies cannot meet them?

Under the requirements of the proposed control plan, Minnesota will have a statewide SO, limit of 224,000 tons per year for 1990, going down to 194,000 tons per year after 1994. Tr. 15, pp. 124-135; SONAR, pp. 556-567. To comply with the limits set for the state for 1990, the Agency proposes a systemwide emissions cap for electric generating facilities in Minnesota which have a total combined net generating capacity greater than 1,000 megawatts. At the present time, the caps apply only to NSP and MP. The control plan establishes an upper limit or cap on Minnesota Power of 43,000 tons per year by 1990. Northern States Power is required to meet a cap of 89,700 tons per year by 1990. In addition, the Agency has proposed that the owner or operator of any electric generating facility with heating equipment having a heat rate greater than 5,000 MM/BTU per hour should comply with RACT. The RACT requirement would require NSP to operate the King plant at an annual average emission rate of 1.2 lb./MM BTU by 1990, as compared 2.42 lb. in 1984. SONAR, p. 567. Minnesota Power would be required to operate its Clay Boswell plant in an annual average emission rate of .75 lb./MM BTU, compared to .94 lb. in 1984. Id. This is a 20% reduction for that plant. SONAR, pp. 567, 611; Tr. 15, p. 116: Tr. 28, p. 169. The RACT and the cap requirements are, as a practical matter, interrelated, as the cap cannot be met without meeting the RACT requirement under most circumstances.

NSP Cap

147. NSP fears that it will exceed the proposed 89,700 TPY cap each year

from 1990 through 2005 if no changes in current emission rates are made at NSP coal fired plants. Tr. 24, p. 10. According to NSP, if NSP were to comply with RACT at King, reducing emissions at that plant from 2.1 to 1.2 lb./MM BTU, the cap would be met only for the period of 1996 through 2003. Tr. 24, p. 19; NSP Ex. 291, Figure 7. Thus, the cap would be violated between 1990 and 1996.

MPCA suggests that NSP can, in fact, meet the cap if certain conditions hold: (1) Power generation as forecasted in NSP Ex. 291; (2) Lower emission rate assumptions for other NSP facilities; and (3) The ability to meet RACT at King plant.

148. NSP predicted that Sherco 1, 2 and 3 would emit S02 at a rate of 0.6 lb. SO,/MM BTU. Tr. 28, pp. 175-176. This may not be a correct assumption. Under the current operating permit for Sherco I and 2, the maximum emission rate allowed for the coal used is 0.54 lb. SO,/MM BTU. Id. In addition, the actual emission for Sherco I and 2 between 1982 and 1985 was between 0.36 and 0.45 lb. S02/MM BTU. Id. Based upon historical operation and permit requirements, 0.5 lb./MM BTU is a more reasonable assumption than the 0.6 lb. used by NSP in its calculations. With this lower assumption, it is possible for NSP to meet the cap without modified operation at any of its other plants, except the King plant.

149. Other factors suggest that NSP would not have difficulty meeting a cap requirement. Emission rates at other NSP facilities are actually lower than presented by NSP in their forecast. Emissions at High Bridge, between September and October of 1984 were 1.6 to 1.7 lb. rather than the 3.0 assumed by NSP. PCA Ex. 396, p. 4. In addition, NSP has a limited contract for low sulfur Wyoming coal, which has one-half the sulfur contact of Montana coal. Tr. 26, p. 185. NSP has successfully tested various blends using this coal at the Black Dog, High Bridge and King plants, achieving 1.7 to 1.8 lb. emissions at King. MPCA Ex. 396 and 397; Tr. 28, p. 182.

Two additional factors may also lower NSP emissions, allowing it to more easily meet the cap. First, NSP's energy demand forecast may be over estimated. MPCA Ex. 436. Also, further conservation methods by NSP customers may further reduce demand. Tr. 25, pp. 104 and 161.

150. In conclusion, based on actual historical emission rates and current permit requirements at NSP facilities, it is reasonable to expect that NSP will be able to meet the cap requirement. A possible switch to Wyoming coal and addition conservation measures should relieve even more pressure. All of this depends, however, on NSP's ability to meet the RACT requirement at King.

Minnesota Power Cap

Minnesota Power indicates that it will not be able to meet the cap requirements proposed by the control plan. MP Ex. 4. In making this forecast, however, MP also makes a number of questionable assumptions. First, the forecast is based upon the assumption that MP will not be able to meet RACT Boswell 4. There is no reason to believe that MP cannot be meet RACT with the addition of lime to its scrubber. Therefore, this assumption is invalid. Secondly, MP has reached an agreement to sell 40% of Boswell Unit 4 to NSP. MP's forecast assumed that NSP would operate that facility at a higher capacity than MP had in the past. Information from NSP indicates that they may operate that facility at a lower capacity than its operation in the past. Tr. 28, pp. 172-174. MP has indicated that it may use idle capacity, if it exists. If MP were to do this, however, they would merely be replacing other capacity in their own system, thereby reducing emissions rather than increasing them, because Boswell 4 is one of the cleanest facilities in the area. Tr. 28, pp. 171-173.

The conclusion follows that, according to all the evidence available at this time, Minnesota Power will be able to meet the control plan cap.

Can NSP and MP Comply With RACT & at What Cost

151. RACT is a flexible requirement, which is decided after reviewing all the facts and circumstances applicable to each application. RACT at plant can definitely be different than RACT at another plant. RACT for King and RACT for Boswell will be determined at some time in the future, after the parties have been able to negotiate. If negotiations are unsuccessful, then the companies will have an opportunity for a contested case hearing prior to any final decision on what the requirements of RACT will be. However, it is important for accessing the control plan that some ideas of RACT be discussed at this point, for otherwise there will be no idea of what the cost will be, nor will there be any idea of what the reductions would be. The Agency's representatives were very clear, on the record, that no final decision has been as to what the RACT requirements will be. For example, one was asked a series of hypothetical questions as to whether a scrubber at King, costing $40 million and achieving an emission rate of 1.2 lb. would be required if 1.4 lb. could be achieved by fuel switching at a cost of $5 million per year. Given those two choices, the represented agreed that the fuel switching would be considered compliance with RACT. Another hypothetical was a fuel switch, costing $5 million, which would achieve a 1.2 lb. rate, as opposed to an alternative fuel switch option that costs no additional money, but would only achieve 1.4. In that context, the Agency's representative agreed that the 1.4 lb. rate at no cost would be preferable to the 1.2 lb. rate at a significant cost. Tr. 28, pp. 257-260.

152. The strictest RACT requirement for NSP King would be 1.2 lb. SO,/MM BTU. The RACT requirement may be satisfied through a number of options, each with an associated cost. For example, it could be achieved by the install ation of a scrubber at a cost of $39 to $55 mi 1 1 ion per year. SONAR, pp. 612-614; MPCA Ex. 326. A much less costly alternative is fuel switching. Tr. 28, pp. 118-194.

153. It is not known how long emission levels may be reduced by fuel switching. it is not known what fuels may be burned effectively in the cyclone boiler at King to reduce SO, emissions to the level of RACT, because a proper blend must be found. Tr. 26, pp. 182-187; NSP Ex. 356. NSP has tested a low sulfur Wyoming coal at three of its plants, including King. Those test burns indicated that emissi on levels of at least 1.8 lb. /MM BTU are achievable at King. MPCA Ex. 396 and 397; NSP Ex. 356. But even lower levels may be possible at King, given the optimum blend. Low sulfur Wyoming coal is currently available, although at a somewhat higher cost than Montana coal. Dravo Coal Company has "Compliance" coal which has been burned extensively in a cyclone boiler similar to the one at King. Tr. 27, p. 13. This coal has a BTU rating of 11,300. A cyclone boiler is typically designed to accommodate coal in the 11,000 BTU range. Dravo Coal tested at 1.17 lb. SO,/MM BTU, and

has been burned in a cyclone boiler (but at a plant other than King) at an emission level below 1.2 lb. SO_2/MM BTU. MPCA Ex. 395, Tr. 27, p. 13. It is reasonable to believe that a similar emission level could be achieved in the cyclone boiler at King. Immediate deliveries of up to 1.5 to 2 million tons per year, with a 150 million ton reserve, are available from Dravo Coal Company. Tr. 27, p. 9. Similar coal is available from other companies in that same area. Tr. 27, p. 17. Transportation costs would be higher for Wyoming coal than the Montana coal currently used by NSP. Transportation costs would be somewhat offset, however, by the fact that Wyoming coal has a higher BTU rating. Tr. 27, p. 34.

Given the fact that Wyoming coal has already been test burned at King, and the fact that it has been successfully burned in a cyclone boiler elsewhere at less than 1.2 lb., it is technically possible that RACT could be achieved at King with fuel switching alone. However, tests have not yet been conducted at King to conclusively establish this possibility. It must be concluded therefore, that the question of whether fuel switching alone can reduce the emissions at King to RACT is unknown at this time. It is certainly not out of the question, but it cannot be said to have been proven either.

154. Turning to the issue as to the application of RACT to the Minnesota Power system, RACT may be accomplished at Boswell 4 with the addition of lime to the scrubber on that plant. No additional modifications are required. SONAR, pp. 611-615; Tr. 28, pp. 171 and 205. MP has affirmed its ability to meet RACT with the addition of lime. PCA Ex. 325.

The cost of complying with RACT at Boswell 4, with the addition of lime to the scrubber, is estimated to be $5 million per year, or $5.84 per residential customer. SONAR, p. 616.

Other alternatives may be possible as well, such as fuel switching to Wyoming coals. Tr. 28, pp. 211-212.

Other Means of Achieving Control Plan

155. Reductions in sulfur dioxide emissions can be achieved through the adoption of conservation measures. Although the Agency only briefly addresses energy conservation as a pollution control strategy in the SONAR, other participants presented thorough data on this topic, principally the Department of Energy and Economic Development and North American Water Office.

156. Energy conservation measures can reduce emissions directly by reducing the need for coal fired power generation. By lowering the peak load, the need to operate older, less efficient (and unscrubbed) power plants is reduced. Overall , conservation measures reduce the annual emissions of sulphur dioxide, and also reduce the waste produced by burning coal, even at a scrubber-equipped power plant. Reducing electrical consumption is the cleanest, lowest cost alternative for reducing S02 emissions. But conservation has added benefits as well.

Conservation saves money because it delays the need for additional capital investment, which is almost always at a more expensive rate because new generation systems are more expensive than older systems. For example, electrical energy from the newer Sherco facility costs about $1200 per KWH while generation from NSP's older facilities costs about $400 per KWH. Tr.

27, p. 283. It also reduces the risk of over-investing in pollution control equipment which may not be needed, should a meaningful national pollution control program become a reality. Tr. 25, p. 106; Tr. 22, p. 95.

Conservation also has the advantage of displacing all pollutants, including heavy metals, in addition to sulphur dioxide, whereas other pollution control alternatives, such as smokestack scrubbers, remove only a limited number of pollutants.

1 57 Con serv at i on a s a pollut i on control strategy i s av iab 1 e part i a I alternative to other more costly control measures, such as smokestack scrubbers, and has, in addition, the added advantage of directly saving the consumer money. Tr. 26, pp. 16-17; NAWO Ex. 16. Efficiency improvements could provide possible reductions in sulphur dioxide emissions ranging from 1500 to over 4000 tons per year. Tr. 25, pp. 92, 104-105, and 161. Conservation could account for between 4.7 and 12.1 percent of the projected emissions over the cap forecasted by NSP for its system. NSP Ex. 291, Table 1; Tr. 25, pp. 157 and 175.

158. There are many reasons to account for why technological and conservation improvements are not implemented more quickly than they are. The consumer may lack the resources to implement the conservation measures. In such cases, a more generous rebate program would be a sufficient incentive. In other cases, the consumer may not invest in energy-efficient improvements out of ignorance or inertia. Consumer information seems to be the most important factor. Within reason, penetration of energy conservation and efficiency measures is ultimately a matter of consumer information and education -- or, more bluntly, advertising.

159. Efficiency improvements are cost-effective methods of achieving emission reductions. Examples are found in refrigeration, 'lighting and electric motors. Tr. 25, p. 156; Tr. 24, p. 60. The greatest potential savings are in the commercial and industrial uses, where worthwhile savings are possible even at penetration rates as low as 1% or 2%. Tr. 25, p. 156. Residential refrigerators currently in use consume about 1492 GWH annually. NAWO Ex. 10. More efficient models currently available consume about half that figure, or 750 KWH annually. Tr. 24, p. 91. Technically, the potential for reduced consumption for residential refrigeration could be about 50% for any electrical utility anywhere in the country. The actual potential is likely to be substantially less than that, however, because technological penetration is never immediate nor complete. Tr. 27, p. 223. Information and rebate programs are needed to ensure that when the consumer makes a decision, it will be for the more efficient model. Utilities in Minnesota could do more to promote these energy-efficient products.

160. The potential for savings in commercial lighting, electric motors, and building ventilation is similar. Estimates suggest that efficiency improvements in fluorescent lighting could save as much as 80% with the installation of more efficient lighting ballasts and reflectors. Tr. 24, pp. 133-137. Process motors in NSP's service area constitute 37% of the electricity consumed by NSP's business and industrial customers. NSP estimates that the potential savings due to efficiency improvements in electric motors is no greater than .03%. Tr. 25, p. 86. Available information indicates that this estimate may be too conservative. Tr. 25, p. 86; Tr. 27, p. 243. Savings may range between 10% and 30%. Tr. 25, p. 166. The utilities have only now begun to investigate the concept of variable speed drives and adjustable speed drives on electric fans, which are an integral part of a building's ventilation system. In an older ventilation system, the fan motor runs at full throttle, with the air being regulated by means of dampers. In a variable speed drive system, the speed of the fan motor, and thereby the electrical energy consumed, is itself controlled to accommodate ventilation system needs. The variable speed drive concept could result in substantial reductions in energy consumption and corresponding reductions in pollution.

161. The utilities could pursue additional measures. To some extent, the utilities are still promoting increases in energy consumption. Tr. 25, p. 81. The utilities could require certain mandatory efficiency standards in the case of specific energy uses. For example, the utilities could require super-insulation for new electrically heated homes. Tr. 25, p. 82. The utilities could promote the concept of energy conservation as a pollution control strategy by informing their customers about the relationship between energy consumption and acid rain. Tr. 25, p. 84.

162. Optimistic assessments about the potential of conservation as a pollution control strategy must be tempered by acknowledging that improvements in technology seldom live up to their full potential. Tr. 27, pp. 224, 226-228. The easiest conservation benefits have mostly been achieved already. Consumers may not readily accept additional measures, particularly if they fail to meet consumer tastes in other ways, such as convenience (frost-free refrigerators or self-cleaning ovens) or initial purchase price. Similarly, much of the potential savings due to energy efficiencies in industry already have been achieved as a result of existing economic incentives to reduce energy bills. Tr. 29, p. 222.

Some benefits in reduced emission levels can be expected to be achieved through the promotion of energy conservation. In many cases, this may come at no cost to the consumer, at least in the long run. The use of conservation as a means of reducing emissions must be viewed as a long-term option, not a short-term one. It requires consumer education, incentive programs, and the whole arsenal of measures already in use. At current levels of expenditures, it is unrealistic to expect conservation to achieve the necessary reductions. Only if there is a substantially increased expenditure for education, incentives, etc. can conservation become a meaningful way to reduce emissions.

NSP already has underway intensive conservation and efficiency improvement programs, due in part to the Sherco 3 stipulation agreement, but further reductions are possible, as well as for Minnesota Power.

Economic Value of the Resource at Risk

163. The Agency has presented two different evaluations of the economic

value of the resources at risk. The first is a travel-cost study based upon Department of Natural Resources (hereinafter "DNR") travel expenditure data. SONAR, pp. 593-597. The second is a contingent valuation study, frequently referred to as the Welle study. SONAR, pp. 602-608; MPCA Ex. 324.

164. Contingent valuation is a methodology to measure the monetary value which individuals attach to the preservation, or loss of, environmental amenities which do not, in and of themselves, possess a market value. A travel-cost study, on the other hand, measures actual expenditures by users of a resource, measuring preservation value only indirectly

165. The Agency's travel cost study indicated the economic value of the lake resources at risk somewhere between $1 million to $89 million. NSP's travel cost study suggests the total value of the lake resources at risk is $11.48 million. SONAR, p. 597 ; NSP Ex. 31 8 and Tr. 22 , p. 1 90.

166. The contingent valuation study estimated the value of the resources at risk to be somewhere around $260 million per year, but the author also calculated an absolute lower-bound estimate of $78 million per year. Tr. 27, p. 106. It is found that the contingent valuation study is valid, and that its supports a value of at least $78 million per year.

The travel-cost estimates of both the MPCA and NSP deserve less confidence than the contingent valuation study for a number of reasons. A travel-cost study does not measure "existence values" which individuals would be willing to pay to preserve resource! which they do not use. For example, a person might be quite certain of never visiting Lake of the Woods or Bearskin Lake. Nonetheless, they might be willing to contribute money towards the preservation of those resources. Another problem with a travel-cost study is that it does not measure the "image" or "perception" value of a resource, upon which much of the tourist and recreation business is based. One-half of the resort business in northeastern Minnesota could be lost if resource degradation spoiled the image of the northern lake country. MPCA Ex. 316; SONAR, p. 595.

Travel-cost studies fail to consider the value of numerous small inaccessible lakes and wetlands, resulting in a possible underestimation of the magnitude of the resource at risk. Tr. 14, pp. 63, 68, 73-74. In addition, the NSP travel-cost study was based upon the use-value of fishing alone, and failed to consider parallel uses such as boating, camping, hiking, and so on, unless they included fishing. It also failed to consider that users other than fisherman might be affected by the degradation of the resource. Tr. 23, pp. 122-125 and 205; Tr. 22, p. 81; SONAR, p. 591; and MPCA Ex. 317.

167. The Welle contingent valuation study is the most sophisticated, best planned and most focused attempt to place a total value on the resource. While it does suffer from some starting point bias, the absolute lower-bound estimate of $78 million per year does accommodate that deficiency. In the context of all the information available, it is found that the actual value of the resources at risk is at least $78 million per year. It is not more than

$260 million per year. More precise determination is not possible from this record.

Cost of Control

168. The control plan has two requirements that may increase tie cost of electric generation to utilities and customers: a requirement to meet the emissions cap, and a requirement to apply RACT to boilers with greater than 5,000 million BTU per hour. Currently, this RACT requirement applies only to NSP-King and MP-Boswell 4.

169. Determining the cost of the cap requirements depends upon whether the affected utilities will have to make emission reductions in addition to those required by RACT. To the extent that meeting the RACT requirement will allow the utilities to meet the emission cap limits, no additional modifications will be required, and there would be no additional capital costs.

170. The cost of installation of additional controls to comply with RACT at NSP-King depends, of course, upon the method used to achieve RACT. Ultimately, the details of what RACT will be will not be known for certain

until the permit mod if i cation process is concluded Therefore, any discussion of cost must be understood to be tentative only and are usable only to give decision makers some idea of the magnitude of potential costs involved. NSP-King offers a good example of this uncertainty.

171. For NSP, the "worst case" cost alternative considered, is the requirement that a scrubber be added to the King plant. If this were necessary, the cost could be as much as $55.2 million per year, or $16.40 per residential customer per year. MPCA Ex. 326; SONAR, p. 618. It is possible, however, that RACT may be accomplished by switching to lower sulfur coal. The cost of this option would only be between $5 and $6.7 million per year, or $2.00 per NSP residential customer per year. Tr. 28, pp. 190-193.

172. For Minnesota Power, the cost of RACT is more certain. It will be the cost incurred for the addition of lime to the scrubber at Boswell 4. This is estimated to cost about $5 million per year, which amounts to about $5.84 per residential customer per year. SONAR, p. 616.

Miscellaneous Statutory Requirements

173. This rulemaking proceeding, like all others of the agency, is governed by a variety of statutory provisions. In addition to being required to demonstrate the need and reasonableness of proposed rules, the agency is also required to demonstrate compliance with Minn. Stat. 14.115, which relates to small business considerations in rulemaking. In complying with that statute, the agency included a separate paragraph in its Notice of Hearing indicating the potential impacts on small businesses and referring to a portion of the Statement of Need and Reasonableness for further information. In the Statement of Need and Reasonableness, the agency set forth, in detail, anticipated utility rate increases resulting from the "worst case" scenario of the rules adoption. While none of the utility companies directly impacted by the control plan meet the test of a "small business", the Notice of Hearing aid indicate that phase II controls could be extended to sulfur dioxide emitters who would meet the test of a small business. It is

found that the agency has documented its consideration of the impacts on small business and has given notice of the potential impact on small businesses likely to flow from adoption of the rule.

174. An additional requirement imposed upon the agency is contained in Minn. Stat. 116.07, subd. 6, which directs the agency to "give due consideration to the establishment, maintenance, operation and expansion of business, commerce, trade, industry . . . and other economic factors and other material matters affecting the feasibility and practicability of any proposed action . . . [to] take or provide for such action as may be reasonable, feasible and practical under the circumstances." The agency has, in the Statement of Need and Reasonableness, documented its concern over costs to both business and residential consumers. The hearing record contains evidence concerning the impact of the proposed rule on business in general , and in particular, upon certain businesses served (or proposed to be served) by Minnesota Power. There are public exhibits from mining companies, from the proposed new paper mill in Duluth, the forest products industry, and other affected businesses. There is testimony about the general state of the economy in northeastern Minnesota. On the other hand, there is also evidence in the record about the economic value of tourism, the forest products industry, and other industries

which could be adversely affected by acid deposition. An entire portion of the hearing record is devoted to attempting to place a value on the resources at risk. See, also SONAR pp. 591 - 621. It is concluded that the agency has, to date, given due consideration to the establishment and expansion of commerce and industry and has complied with Minn. Stat. 116.07, subd. 6 (1984).

175. Minn. Stat. 116D.04, subd. 6 (1984), provides as follows:

> No state actions significantly affecting the quality of the environment shall be allowed . . . where such action . . . is likely to cause pollution, impairment, or destruction of the air, water, land or other natural resources located within the state, so long as there is a feasible and prudent alternative consistent with the reasonable requirements of public health, safety, and welfare and the state's paramount concern for the protection of its air, water, land and other natural resources from pollution, impairment, or destruction. Economic considerations alone shall not justify such conduct.

Although the statute initially seems oriented primarily at permits, it must be read in the context of Chapter 116D as a whole. Read in the broader context, there is no reason to believe that it does not apply to rulemaking, so long as it can be shown that the rulemaking "significantly affect[s] the quality of the environment". There can be no question that the adoption of a standard and the imposition of a control plan is at least an attempt to "significantly affect the quality of the environment". This becomes even more clear when other sections of the act are considered, including the general policy provisions in 116D.03, subd. 2(a), (b), (c), (d), (h), (i) and (j), and in addition, Minn. Stat. 116D.03, subd. 2 (a), (c) and (e). The latter, for example, directs all state agencies to:

> Recognize the worldwide and long-range character of environmental problems and, . . . lend appropriate support to initiatives, resolutions and programs designed to maximize interstate, national and international cooperation in anticipating and preventing a decline in the quality of mankind's world environment.

The import of the applicability of Minn. Stat. 116D.04, subd. 6, comes from the last sentence, which provides that economic considerations alone shall not justify harmful conduct.

176. It has been suggested that the agency is required to set the acid deposition standard at a level which will meet not only the concerns of the Acid Deposition Control Act, but also meet the concerns of the state's Water Quality Rules, Minnesota Rules Part 7050.0110, et seg. In particular, it is noted that Minn. Rule Part 7050.0210, subp. 13, provides as follows:

No sewage, industrial waste or other wastes shall be discharged into the waters of the state in such quantity or in such manner, alone or in combination with other substances as to cause pollution thereof as defined by law.

It is concluded that the rule is not violated because there is no showing that any reasonable state standard would materially alter the ph of the waters in a fashion different from the proposed 11 kg/ha/yr standard. The "no standard" alternative is rejected as (a) contrary to the Acid Deposition Control Act, and (b) anthetical to the goals of both that act and the Water Quality Rules.

177. It has also been suggested that adoption of the proposed standard would violate federal law because the Boundary Waters Canoe Area Wilderness has been designated by Congress as a federal wilderness area, which by definition, implies a prohibition against any degredation of natural resources in the area. This argument is rejected because the difference (to the wilderness) between the 11 kg/ha/yr standard and any standard which could be considered to be reasonable under this record is so minimal that it would not materially assist in attaining or preserving "pristine" conditions in the wilderness area. The only way that such a goal could be achieved is through national action.

Based upon the foregoing Findings of Fact, the Administrative Law Judge makes the following:

CONCLUSIONS

1. That the Agency gave proper notice of the hearing in this matter.

2. That the Agency has fulfilled the procedural requirements of Minn. Stat. 14.14, and all other procedural requirements of law or rule.

3. That the Agency has documented its statutory authority to adopt the proposed rules, and has fulfilled all other substantive requirements of law or rule within the meaning of Minn. Stat. 14.05, subd. 1, 14.15, subd. 3 and 14.50 (i) and (ii).

4. That the Agency has demonstrated the need for and reasonableness of the proposed rules by an affirmative presentation of facts in the record within the meaning of Minn. Stat. 14.14, subd. 2 and 14.50 (iii).

5. That the amendments to the proposed rules which were suggested by the Agency after publication of the proposed rules in the State Register do not result in rules which are substantially different from the proposed rules as published in the State Register within the meaning of Minn. Stat. 14.15, subd. 3, Minn. Rule 1400.1000, Subp. 1 and 1400.1100. The Agency complied with the recommendation of the Administrative Law Judge that it mail notice of one of its changes to all potentially affected Minnesota utilities. .

6. That any Findings which might properly be termed Conclusions and any Conclusions which might properly be termed Findings are hereby adopted as such

7. That a finding or conclusion of need and reasonableness in regard to any particular rule subsection does not preclude and should not discourage the from further modification of the rules based upon an examination of the public comments, provided that no substantial change is made from the proposed rules as originally published, and provided that the rule finally adopted is based upon facts appearing in this rule hearing record.

Based upon the foregoing Conclusions, the Administrative Law Judge makes the following:

RECOMMENDATION

It is hereby recommended that the proposed rules be adopted consistent with the Findings and Conclusions made above.

Dated this 27th day of June, 1986.

ALLAN W. KLEIN
Administrative Law Judge

NOTICE

Pursuant to Minn. Stat. 14.62, subd. 1, the agency is required to serve its final decision upon each party and the Administrative Law Judge by first class mail.

Reported: Court Reported - Lerschen & Associates, primarily;
Assorted Others, secondarily.

MEMORANDUM

I

It is reassuring that this thorough hearing on acid deposition in Minnesota produced more good news than bad news. The bad news is that acid deposition does, in fact, exist. There are questions that do not yet have precise answers, in part because different lakes and different organisms all react differently to the acid. But, the broad outlines of all of the answers are known. It is important that the gradual increase in acid deposition which must have occurred in Minnesota over the last century not be allowed to continue unabated. While we do not require a "crash program" or "declaration of war" on the problem, neither can we ignore it. The Agency's proposal, which will cost NSP residential customers a maximum of $ 16.40 per year (worst-case), and Minnesota Power's residential customers $ 5.84 per year, is needed, and it is a reasonable approach to the problem.

In the good news category, no Minnesota lake has been acidified by man-made acid deposition -- yet. No trees have been killed, no crops have been damaged, nor have any animals become extinct as a result of man-made acid deposition in Minnesota. Unlike our neighbors to the east, Wisconsin and

Michigan and particularly unlike east coast states such as New York and New Hampshire, Minnesota is blessed with enough acid neutralizing particles which naturally occur in our atmosphere to reduce the acidifying potential of the sulfur dioxide and sulfate which is present. Rainfall on the east coast is substantially more acidic than it is in Minnesota, and a well-defined gradient does exist across the upper midwest area, with Minnesota having the least acidic precipitation, Wisconsin's being more acidic and Michigan's being even more acidic.

An additional category of "good news" is the environmental consciousness of this state, and the resultant pollution control devices already installed and operating here. For example, NSP, our largest utility, scrubs 47 percent of its coal-fired generating capacity. Minnesota Power scrubs 88%. The national average is only 16%. Scrubbers are already installed on our largest units (of the four largest units in Minnesota, the King plant is the only one without a scrubber). But even if the comparison is focused upon all coal-fired utility facilities, not just the big ones, Minnesota has an exemplary record. For example, Virginia is the only state east of Minnesota that emits sulfur dioxide at a lower average emission rate (1.4 lb.SO2/MM BTU) than Minnesota (1.5 lb SO,/MM BTU). The comparable figures for Wisconsin are 3.4 and for Michigan 1.8. The total sulphur dioxide emissions from Minnesota in 1980 were 236,000 metric tonnes. Wisconsin emitted 578,000 metric tonnes, and Michigan 823,000 metric tonnes.

It is also "good news" that we are taking action simultaneously with other states and provinces in our region. They can substantially affect the acid deposition in Minnesota, and we can help them. Actions in Minnesota alone cannot meet the 11 kg/ha/yr acid rain standard. The prevailing winds that enter our state cannot be neutralized at the border. We are dependent on the actions of other states and provinces to achieve compliance with our own Minnesota standard. Significant emission reductions by Alberta, Manitoba, Wisconsin and Michigan will be a big help. If the regional strategy continues to develop, we can feel somewhat better about the inaction at the federal level.

In sum, although this Report concludes that acid deposition is a problem and that the Agency's control plan is needed (and reasonable), Minnesotans can feel some relief that none of our resources have been irrevocably damaged as yet. We can also take pride in how well we have done so far. Although adoption of the Agency's control plan will cost us money, it is a rational and prudent plan that will avoid having to fashion a "crash program" in the future.

II.

The fundamental test which the Agency must meet in order to adopt these rules is that of reasonableness. The greatest obstacle to the Agency's meeting that test is the uncertainty of scientific principles in the area of acid deposition, and the absence of conclusive data to demonstrate the precise application of those principles to Minnesota's situation.

The term "acid rain" was originally coined in 1872 by an English chemist, Robert Angus Smith. The first links between atmospheric deposition and terrestrial ecosystems were established even earlier. However, it has only been within the last 30 years that massive research has been undertaken to establish, as precisely as possible, the effects of acidic deposition on the environment, to quantify the resources at risk, and to determine source-receptor relationships. In Minnesota, awareness and concern about acid deposition's impact did not begin until 1976, and the first legislative action was only in 1980. SONAR, pp. 19-22. It should not be surprising, therefore, that there are gaps in our knowledge, both in fundamental principles and specific localized applications. We simply have not been studying the problem long enough to have all the answers. We do know that acid deposition exits. We do know sulfate is one of the principle components of acid deposition in Minnesota. We do know that the principle contributor to atmospheric sulfate in Minnesota is industrial emissions. We do know that the combustion of coal for the generation of electricity is a primary contributor to those emissions. All of these Items were initially questioned, but are no longer in doubt. The answers to the other issues still evade our grasp, primarily because of insufficient time. Reliable data on long term trends, particularly local ones, is simply nonexistent. But, as noted below, we often have to act in the face of insufficient data or scientific uncertainty.

What is in doubt is precisely how much deposition is too much for any given geographic area, such as Minnesota. The Agency has recommended that the standard be set at 11 kg/ha/yr of wet deposition as an annual standard. Others have suggested 20, others 16, and still others 8. Some have suggested that the standard be a three year average rather than one year. Although the Administrative Law Judge has found the Agency's recommended standard to be reasonable, he cannot express, for scientific certainty, that it is the highest possible number. The Agency staff does not make that claim, and any person who did make such a claim would be ignoring the uncertainty which must be recognized to exist at the present time.

A legitimate question arises as to the burden of proof which the Agency must carry in order to be allowed to adopt its standard in the face of scientific uncertainty and imperfect data. This question has arisen infrequently in Minnesota, but often enough on the federal level (and in other states) to allow reliance on precedent to assist in answering it.

The Minnesota Supreme Court, in the case of Manufactured Housing Institute v. Pettersen, 347 N.W.2d 238 (Minn. 1984), has given us guidance for answering these questions. In that case, the Commissioner of Health, in response to a legislative directive, determined that formaldehyde in building materials did pose a significant health problem. He announced-that he would soon propose a rule establishing a maximum formaldehyde level in new housing units.

The Commissioner proposed a rule setting a maximum formaldehyde level of

0.4 ppm. After extensive proceedings, including several thousands of pages of hearing testimony, public comments, and studies prepared by both advocates and objectors to the proposed standard, an ALJ found that the Department of Health had failed to justify the reasonableness of 0.4 ppm standard. He found that there was nothing in the record to justify the selection of .4 ppm rather than .1, .3 or .6, other than the fact that the lesser the concentration that exists, the less chance there is that any effects would be felt. He described the proposed level of .4 ppm as being like "picking a number out of a hat". The ALJ found, however, that the record would support the reasonableness of a .8 ppm standard. At that level, most persons become aware of the presence of formaldehyde, and both the Formaldehyde Institute and its expert consultant admitted that above a level of .8, there would be irritation for most people.

Because the ALJ had made a negative finding, the report was submitted to the Chief Administrative Law Judge for his review. The Chief ALJ reviewed the decision, agreed that the .4 ppm was unjustified, but concluded that a limit of".5 ppm or higher" would be acceptable. He did not explain how he picked the .5 ppm number.

The Commissioner adopted the Findings of the ALJ, as modified by the Chief ALJ, and went on to adopt the .5 ppm level without further explanation. Industry persons appealed the Commissioner's determination, and following a series of procedural moves that are not important here, the appeal reached the Supreme Court.

Justice Simonett, writing for the Court, found the Commissioner's conclusion that .5 ppm was reasonable to be "most troublesome". 347 N.W.2d 245. He wrote:

> It is difficult, it seems to us, not to characterize this unexplained selection of 0.5 as arbitrary. Simply saying that a particular level is reasonable does not make it so, especially where the Commissioner otherwise apparently adopts the factual findings . . . of the Hearing Examiner . . which stressed the disparity of the various study results. Arguably, the Commissioner selected 0.5 ppm because the Chief Hearing Examiner selected it. Bit the Chief Hearing Examiner failed, as well, to give any reasons in his findings and conclusions as to why he rejected 0.8 ppm, and instead chose 0.5 ppm.

> We hold, therefore, that the Commissioner of Health's determination, as articulated by him . . . is arbitrary and capricious and violates substantive due process. In so holding, we do not substitute our judgment for that of the Department of Health. He do not purport to evaluate the merits of the conflicting scientific evidence nor to supply our own "legislative facts" to arrive at an appropriate public health policy. We say only that having made a careful and close scrutiny of the Commissioner's action, we find that there is no explanation of how the conflicts and ambiguities in the evidence are resolved, no explanation of any assumptions made or the suppositions underlying such assumptions, and no articulation of the policy judgments. In short, there has been no reasoned determination of why a level of 0.5 ppm was selected. 347, 245-246.

The Court also noted, in a footnote:

> This requirement that the agency explain its determination is not some idle exercise in judicial officiousness. The purpose of "articulated standards and reflective findings" is to ensure "furtherance of even-handed application of law, rather than impermissible whim, improper influence, or misplaced zeal". Reserve Mining Co. v. Herbst, 256 N.W.2d

808 825 (1977), quoting Greater Boston Television Corp. v. F.C.C., 444 F.2d 841, 852 (D.C. Cir. 1970).

More importantly, for purposes of determining the appropriate standard for Administrative Law Judge to apply to an Agency's action in the face of scientific uncertainty, is the the Supreme Court's adoption of the federal case law in the area of scientific uncertainty. It is important not to loose sight of the difference between judicial review of an Agency's action and ALJ review in the initial rulemaking setting, and of the difference between Federal and State rulemaking. One of the leading cases, which was cited and paraphrased by the Minnesota Court, is Ethyl Corporation v. EPA, 541 F.2d I (D.C. Cir. 1976), cert. denied 426 U.S. 941 96 S.Ct. 2662, 49 L.Ed.2d 394 (1976). In that case, Congress empowered the Environmental Protection Agency to regulate gasoline additives whose emission products "will endanger" public health or welfare. Following a number of studies, the agency took action against lead, ordering annual reductions in the lead content of gasoline. Following a series of procedural steps, the issue of whether or not the Agency's Order was arbitrary and capricious was addressed to the United States Court of Appeals for the District of Columbia Circuit, in an en banc proceeding. Judge J. Skelly Wright, writing for the majority, explained the standard to be used in reviewing decisions in such cases:

> Where a statute is precautionary in nature, the evidence difficult to come by, uncertain, or conflicting because it is on the frontiers of scientific knowledge, the regulations designed to protect public health, and the decision that of an expert administrator, we will not demand rigorous step-by-step proof of cause and effect. Such proof may be impossible to obtain if the precautionary purpose of the statute is to be served. Of course, we are not suggesting that the administrator has the power to act on hunches or wild guesses. Amoco makes it quite clear that his conclusions must be rationally justified. [Amoco Oil Co. v. EPA, 501 F.2d 722, 740-741]. However, we do hold that in such cases the administrator may assess risks. He must take account of available facts, of course, but his inquiry does not end there. The Administrator may apply his expertise to draw conclusions-from suspected, but not completely substantiated, relationships between facts, from trends among facts, from theoretical projections from imperfect data, from probative preliminary data not yet certifiable as "fact", and the like. We believe that a conclusion so drawn - a risk assessment - may, if rational, form the basis for health-related regulations under the " will endanger" language
>
> All of this is not to say that Congress left the administrator free to set policy on his own terms.. Operating within the prescribed guidelines [of the statutes], he must consider all the information available to him. Some of the information will be factual, but much of it will be more speculative - scientific estimates and "guesstimates" of probable harm, hypotheses based on still-developing data, etc. Ultimately, he must act, in

part, on "factual issues" but largely on choices of policy, on an assessment of risks, [and] predictions dealing with matters on the frontiers of scientific knowledge.

Amoco, supra, 501 F.2d at 741. A standard of danger - fear of uncertain or unknown harm - contemplates no more.

Ethyl, 541 F.2d at 28-29

Judge David Bazelon, the Chief Judge of the Ethyl Court, has written on the topic of scientific uncertainty on a number of occasions. He has said:

> Questions of this sort pose difficult - if not impossible - problems for decisionmakers. The experts are likely to disagree about the underlying facts, which are usually both complex and uncertain; they are even more likely to disagree about the inferences to be drawn from those facts. Postponing a decision may sometimes provide the opportunity to reduce uncertainty. But a decision not to decide, or to delay deciding, is still a decision. Both time and information can be costly resources.

Bazelon, Coping with Technology Through the Legal Process, 62 Cornell Law Review 817, 820 (1977).

Rather than have "technically illiterate" judges attempt to second-guess trained experts, Bazelon would have judges focus upon the process used by decisionmakers to make sure that it is thorough, complete, and rational. He notes:

> By articulating both their factual determinations and their value preferences, and by attempting to separate the one from the other, administrators make possible effective professional peer review, as well as legislative and public oversight. With respect to scientific, factual determinations, decisionmakers should disclose where and why the experts disagreed as well as where they concur, and where the information is sketchy as well as complete. Other experts who are steeped in the subject matter - in academe, in government, in industry - can then evaluate the Agency's factual determinations, bring new data to light, or challenge gaps in reasoning. And if individuals or groups differ with the Agency's value choices, they can make their views known in the various public forums. When the reasons for decisions are fully disclosed, there is a genuine opportunity to seek reconsideration in light to new knowledge or changing values.
>
> Necessarily, action may have to be taken in the face of uncertainty, before all the information is available. But awareness of our ignorance puts us ever on the lookout for better and more certain information. And it gives reason to hope that erroneous decisions will not be set in concrete.

Bazelon, Id., at 823-824.

Had the process suggested by Judge Bazelon been followed in the Manufactured Housing case, a remand would have been unnecessary. You will recall that the Chief ALJ and the Commissioner of Health determined that it was appropriate to adopt a rule setting the maximum level of formaldehyde at

0.5 ppm. The problem which the Supreme Court had with that decision was not that the Court thought that 0.4 or 0.6 was a better figure; the problem was that the basis for the 0.5 figure was not explained. It was impossible for the Supreme Court to know whether 0.5 ppm was a reasonable number or not because there was no explanation of how it was selected.

In the case of the Agency's proposed acid deposition rules, the staff has not repeated the error of Manufactured Housing. Instead, it has followed the advice of the Ethyl court, and Chief Judge Bazelon. It has, in the SONAR and in response to questions during the hearing, admitted the weaknesses in its position, admitted where data was lacking, and admitted where the science was uncertain. Some of the other participants came forward with evidence which filled some of those gaps. But, for the most part, the evidence brought forth by others highlighted the uncertainties and cast doubt upon the Agency's presentation. But, based on the authority above, it is concluded that the Agency has demonstrated the reasonableness of its position and that it may proceed, even though questions still remain.